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55th Annual Meeting

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Industrial Hygiene, Safety and Fire Prevention

The war focused attention on safety, industrial hygiene, and fire prevention in industry, and many persons were given training courses in one or more of these fields. Since engineers play an important part in industrial operations, and in the design and construction of buildings and other projects where human welfare is important, there is an increasing realization of the shortcomings of traditional engineering training in fitting engineers to play their proper part in the safety and health of workers and occupants of buildings.

An increasing number of persons believe that every engineer should know enough about safety, industrial hygiene, and fire prevention to be aware of the problems that are involved, and to know when to secure expert assistance in such matters. One suggestion is that college courses be organized in each of the three fields. Unfortunately, curricula are already overcrowded, and there is constant pressure to include other things in them. Such courses do not seem to be possible, except as electives, in which only a few students would be reached.

Another suggestion is that training in these subjects be integrated into existing courses. This plan has much to commend it, but it is not easy to attain. Many instructors are not sufficiently aware of the safety and health aspects of their courses as to be able to present much of benefit without assistance. Textbooks are usually deficient in this respect.

Various organizations, such as the National Safety Council and the National Fire Prevention Association have been working on phases of this problem for some time. Various committees and other agencies have also been interested. Some colleges have undoubtedly made progress, and at the present time four engineering colleges have organized Safety Engineering Departments in cooperation with the National Safety Council.

During the past summer President Huber O. Croft appointed a committee on Industrial Hygiene, Safety and Fire Prevention, consisting of the following:

Professor G. H. Dunstan, University of Alabama, Chairman
Professor W. F. O'Connor, New York University
Professor W. N Cox, Georgia School of Technology
Professor J. J. Ahern, Illinois Institute of Technology
Professor R. A. Moyer, Iowa State College
Mr. W. P. Hughes, National Safety Council
Mr. John Roche, National Safety Council

This committee will attempt to stimulate interest in these fields, as well as indicate sources of information to aid instructors in giving instruction in these subjects. It will attempt to avoid duplicating the efforts of others who

are interested in these fields, and in order to do so, the chairman will welcome information and comments from any source relative to studies and comments of any nature along these lines. This material may be sent to Professor G. H. Dunstan, Box 1996, University, Alabama. It is hoped that a report can be prepared in time for presentation at the annual meeting this summer.

Dear Sir:

At the Eleventh Annual Meeting of the **Southwest Section,** A.S.E.E., the following officers were elected:

Chairman—O. A. St. Clair, Texas Technological College.

Vice Chairman—H. C. Dillingham, A. & M. College of Texas.

Secretary-Treasurer—W. C. May, University of New Mexico.

Member of General Council—W. R. Woolrich, University of Texas.

H. C. DILLINGHAM, *Secretary.*

A Reexamination of the Compton Report in the Light of Enrollment in Engineering Curricula, Fall of 1946*

By HENRY H. ARMSBY

Specialist in Engineering Education, U. S. Office of Education

At the 54th annual meeting of the Society for the Promotion of Engineering Education (now the American Society for Engineering Education) in June, 1946, a committee of the Society under the chairmanship of Dr. K. T. Compton presented a report entitled "The Outlook in the Demand for and Supply of Engineering Graduates." This report, which is referred to in this discussion as the Compton Report, represented a sincere effort to estimate the future demand for and supply of engineering graduates in the United States, as an aid to the engineering colleges in their planning for the future.

The Compton Report

The Compton report covered only the six major fields of engineering—aeronautical, chemical, civil, electrical, mechanical, and mining-metallurgical—without any implication that the other fields are less important. Only the needs for engineering graduates within the United States were taken into account, although the committee recognized the great demand which will be made on the American engineering profession to help in the reconstruction of the devastated areas of the world.

One hundred twenty-five industrial companies broadly representative of the nation's industrial organization completed and returned questionnaires sent out by the committee, giving certain information about their past employment of engineers and estimates of their future needs. The returns to these questionnaires are given in detail in the report, which appeared in the Journal of Engineering Education in September, 1946. They show several very interesting trends, one of which is the pronounced increase in the emphasis being placed on research and development by the companies answering the questionnaire. Practically without exception these companies had increased their ratio of research engineers to total engineers since 1938, and expected to increase it still further in the future. The number of engineers engaged in research and development had increased by 82 per cent from 1938 to the time of the study, while those employed in production, management, and sales had increased by only 36 per cent. The ratio of research engineers to total engineers in 1938 was 0.76; at the time of the report it was 1.01; and the ratio among prospective employees was 1.44.

* Talk delivered before the Engineering Division of the Association of Land-Grant Colleges and Universities, December 16, 1946.

Not only were the companies increasing the ratio of research engineers to total engineers, but in the research field they were also increasing the percentage of engineers holding advanced degrees, while the opposite was true in the production field.

The returned questionnaires represented a sampling of the industrial employment of engineers, but unfortunately the committee did not know what fraction of American industry was represented by the 125 companies. The committee was therefore able to use the figures from industry only as indices and qualitative measures.

To arrive at a quantitative measure of needs the committee turned to the Bureau of Labor Statistics of the U. S. Department of Labor, which at the time was engaged in a study of the need for engineers. The Bureau of Labor Statistics had computed the ratio of engineers to total employment in each of the nation's principal industrial activities, and had estimated the total employment in each of these activities under conditions of "full employment." The committee felt that it was conservative in assuming that these ratios would be at least as high in the future as in 1940, in spite of the fact that their values, after increasing from 1930 to 1940, had decreased from 1940 to 1944.

The 1940 census shows that the total number of employed persons in the United States in 1940 was about 45 million, of whom about 246 thousand were engineers (in addition, there were 15 thousand engineers unemployed in 1940). Under conditions of "full employment" the Bureau of Labor Statistics estimated total employment at 57½ million persons. Using the 1940 ratios in the various industrial activities the "full employment" needs for engineers were found to be 337 thousand engineers.

The committee assumed further that "full employment" would be achieved by 1950. Since there were 261 thousand engineers in 1940, 76 thousand must be added during the decade 1940 to 1950, in addition to the number needed to offset attrition due to death, retirement, and leaving the profession.

Total attrition was estimated to be 78 thousand for the decade, making a total of 154 thousand additional engineers needed during the decade. According to annual reports of SPEE about 57 thousand first degrees were granted from 1940 to 1945, and it was estimated that 7 thousand degrees would be conferred in the Spring of 1946, making a total of 64 thousand degrees granted through 1946. There would therefore be needed between 1946 and 1950 an additional 90 thousand engineers, or about 23 thousand per year through 1950.

The committee's estimated annual need is about 9.4 per cent of the number of engineers employed in 1940. The industrial questionnaires indicated an estimated need for annual increases of about 17 per cent of present employment. The difference between these estimates is at least partially accounted for by the fact that in an individual company there is a fourth kind of attrition which does not enter into the national picture—that of men transferring from one company to another. This fourth type of attrition is almost impossible to measure but should be considered in comparing the Bureau of Labor Statistics and industrial data.

The committee listed several reasons for believing that this estimated need of 23 thousand engineers per year for the next four years might be too low, and pointed out that the 23 thousand per

year is a short-term requirement. After full employment is achieved the annual need for engineers will be only the number needed to care for the small increase in population, plus the number made necessary by further increases in the ratios of engineers to total employment, plus replacements. This need was estimated at about 18 thousand per year, which is 50 per cent above the number the engineering colleges were graduating prior to the war.

Both the industrial questionnaire and the opinion poll, which was conducted by representatives of the American Telephone and Telegraph Company, bore out the increased dependence of industry upon engineering and indicated that future needs for engineers would be much larger than past needs.

The report called attention to the large need in industry for semi-professional workers of the type provided by ESMWT courses and by technical institutes. The committee estimated that the short term needs for technical institute graduates will approximate 75 thousand per year, and expressed doubt as to the ability of the nation's technical institutes to meet this demand.

In its study of the prospective supply of engineering graduates to meet these needs, the committee estimated the maximum capacity of engineering schools in the United States to be 155 thousand, or 37 per cent above the previous maximum enrollment of 113½ thousand in 1942-43. It was assumed that the number of first degrees granted would continue to be 53.8 per cent of the number of registered freshmen four years earlier, as it was prior to 1941, and that the corresponding ratios for sophomores and juniors would continue to be 64.7 per cent and 71.8 per cent respectively. It was also assumed that the freshmen enrollment in engineering would bear the same proportionate relation to total undergraduate enrollment which obtained in 1941, namely 36½ per cent, which would mean freshmen classes for 1946 and 1947 of 56½ thousand, on the basis of a total enrollment of 155 thousand. Certain assumptions were made as to the proportion of veterans and non-veterans who would follow accelerated curricula.

Based on these assumptions and on the estimate that the current deficit in engineering graduates was 8 thousand, the committee worked out a tabulation showing the expected numbers of first degrees to be granted during each year up to and including 1952. (See page 38 of the printed report of the committee.) Starting with the deficit of 8 thousand and adding the 23 thousand estimated as needed in 1946 gave a total demand for 1946 of 31 thousand, which could be only partially filled by the 7 thousand first degrees to be granted in 1946, from which must be substracted 1½ thousand whom it was assumed would enter graduate schools. This left a net deficit for 1946 of 25½ thousand. Continuing by this process the committee arrived at the conclusion that the deficit of graduate engineers would be filled by 1952, and pointed out that "This means that the need for continuing engineering education at an overload level will lessen beginning with the entering freshman class in 1949."

Enrollment in Engineering Curricula, Fall of 1946

The Compton Report listed a few of the many uncertain factors which influence the future needs for and supply of engineers, and pointed out that the limit of reliability of any such estimate must necessarily be rather wide. However, when this report was presented

few responsible persons in the field of education foresaw the tremendous numbers of veterans who would seek college admission in the fall of 1946. The estimates of the committee as to the prospective supply of engineers were based on what the engineering schools had stated to be their maximum capacity of 155 thousand students, including 56½ thousand engineering freshmen. Actual enrollment this fall is about 223 thousand, including about 92.6 thousand freshmen! These are estimates based on data reported to the Secretary of A.S.E.E. by the institutions which up to December 1, 1946, had submitted complete reports differentiating veterans from non-veterans. Details are set forth in the tables which accompany this discussion.

Table I contains estimates in thousands of students of the enrollment in all colleges and in engineering colleges for November, 1945, and November, 1946. The figures covering all institutions are taken from a report of the Research and Statistical Service of the U. S. Office of Education, based on a sampling survey believed to be accurate within 5 per cent. According to these estimates, college and university enrollment has more than doubled since last year. The enrollment of men is nearly four times that of last year, and of veterans 20 times that of last year, while the ratio of veterans to all men has increased from 14 per cent to 77 per cent.

The second section of Table I, dealing with engineering schools, contains estimates of the total engineering enrollment in the United States for the two years, based on the enrollment of the 90 institutions previously mentioned. These enrollments were compared with the enrollments reported by the same institutions in 1945, and in order to extrapolate them to the entire country were referred back to the same institutions in 1940, the year in which the SPEE enrollment report covered the largest number of institutions, namely 147. The assumption was made that the enrollment in these 90 institutions would constitute the same proportion of the total engineering enrollment in 1945 and in 1946 which it constituted in 1940.

A comparison of the ratios in the last column of Table I shows that the enrollment in engineering schools has increased at a greater rate than that for

TABLE I

COMPARISON OF ENROLLMENTS IN ENGINEERING AND ALL HIGHER EDUCATION, 1945 AND 1946

(Estimates in Thousands of Students)

(Prepared by Henry H. Armsby, U. S. Office of Education, from estimates prepared by the Research and Statistical Service of the U. S. Office of Education and data supplied by the American Society for Engineering Education.) December 6, 1946.

Enrollment	November 1945	November 1946	Ratio of 1946 to 1945
All Institutions			
Total Enrollment	952.0	2078.1	2.18
Men	370.0	1417.6	3.84
Women	582.0	660.5	1.13
Veterans	50.0	1080.4	20.00
Ratio of Veterans to Men	14%	77%	5.50
Engineering Schools			
Total Enrollment	65.3	223.0	3.40
Men	47.3	222.0	4.70
Women	1.8	1.5	0.90
Veterans	16.5	154.0	9.35
Ratio of Veterans to Men	25%	69%	2.76
Ratio of Engineering Students to all Students in Higher Education	6.5%	10.6%	1.63

TABLE II

UNDERGRADUATE ENROLLMENTS IN 90 ENGINEERING SCHOOLS BY CLASSES, 1945 AND 1946

(Thousands of Students)

(Prepared by Henry H. Armsby, U. S. Office of Education, from data supplied by American Society for Engineering Education.) December 6, 1946.

Class	November, 1945			November, 1946			1946 Total ×1.9
	Total (1)	Veterans (2)	% Vets (3)	Total (4)	Veterans (5)	% Vets (6)	
Freshman	16.9	5.1	30%	48.8	32.7	67%	92.6
Sophomore	5.7	2.1	37%	30.2	21.8	72%	57.5
Junior	3.6	1.1	31%	17.8	13.4	75%	33.8
Senior	2.0	0.5	25%	12.3	9.2	75%	23.4
Fifth Year	—	—	—	0.4	0.3	75%	0.8
Regular Students	28.2	8.8	31%	109.5	77.4	71%	208.1
Other	4.7	0.7	15%	7.8	3.7	47%	14.9
Total	32.9	9.5	29%	117.3	81.1	69%	223.0

all colleges and universities, and that the men enrolled in engineering have increased faster than the men in all colleges. This is shown very strikingly in the last figures at the bottom of the table, which show that the percentage of engineering students to all college students has increased since last year from 6½ per cent to 10.6 per cent. This bears out many statements and estimates to the effect that the veterans would show a very lively interest in engineering as a result of their war experiences.

Table II contains in columns 1, 2, 4, and 5 the engineering enrollments in the 90 institutions on which the estimates of this report are based. Columns 3 and 6 show the percentage of veterans to total enrollment in each class and for the total of the 90 institutions.

The figures in the last column of Table II are obtained by multiplying the figures in column 4 by the factor 1.9, which is the ratio of the estimated national total of 223 thousand to the 117.3 thousand reported by the 90 institutions. The information available did not permit the computation of separate factors for the various classes.

Table III is an extension of a table presented in the Compton Report which gave the distribution of engineering students by classes for the year 1939–40 and for April, 1946. To these distributions have been added those for November, 1945, and November, 1946, computed from the SPEE report for 1945 and from the reports of 90 institutions for 1946. The Compton Report stated that in the opinion of the committee the distribution by classes in 1939–40 was about a normal one and that during the war this distribution had become badly skewed. The distribution for November, 1945 is even more skewed than that quoted by the committee for April, 1946, but it is interesting to note that the distribution for 1946 is closer to normal, and the distribution of veterans still closer, if we consider that the distribution for 1939–40 is a normal one.

TABLE III

PERCENTAGE DISTRIBUTION OF UNDERGRADUATE ENGINEERING STUDENTS BY CLASSES, 1939 TO 1946

(Prepared by Henry H. Armsby, U. S. Office of Education, from data supplied by American Society for Engineering Education.)

Class	All Students				Veterans	
	1939–40	Nov. 1945	Apr. 1946	Nov. 1946	Nov. 1945	Nov. 1946
Freshmen.....	34.2	57.6	52.1	44.5	57.4	42.1
Sophomore.....	25.9	21.2	23.9	27.5	24.1	28.2
Junior.....	21.0	12.7	14.5	16.3	12.3	17.3
Senior.....	18.0	8.2	7.9	11.2	6.0	12.0
Fifth Year.....	0.9	0.3	1.6	0.5	0.2	0.4
	100.0	100.0	100.0	100.0	100.0	100.0

Table IV is an extension of a similar table published in the Compton Report, to which have been added distributions for November, 1945, November, 1946, veterans in November, 1946, and a distribution by classes (in columns 8 to 11 inclusive). The sources of these figures are the same as for those in Table III.

It is interesting to note that the expected rush of veterans into aeronautical and electrical engineering has apparently not developed. Aeronautical engineering has actually declined since last year, and electrical engineering has declined since last April, although it is one per cent higher than it was last fall. The largest increases are in civil and mechanical engineering, and this is particularly true among the veterans.

The distribution by classes is of interest, although the distribution of the freshman class probably is not very significant, since included in the 43 per

TABLE IV

PERCENTAGE DISTRIBUTION OF UNDERGRADUATE ENGINEERING STUDENTS BY CURRICULA, 1910 TO 1946

(Prepared by Henry H. Armsby, U. S. Office of Education, from data supplied by American Society for Engineering Education.) December 6, 1946.

Curriculum	All Students							By Classes November 1946				Veterans November 1946
	1910–11 (1)	1920–21 (2)	1930–31 (3)	1940–41 (4)	Nov. 1945 (5)	Apr. 1946 (6)	Nov. 1946 (7)	Fresh. (8)	Soph. (9)	Jun. (10)	Sen. (11)	(12)
Aeronautical.....	—	—	2.7	3.7	4.8	4.9	3.2	2.8	4.1	4.3	4.8	3.3
Chemical.....	2.9	11.1	8.8	16.0	10.0	9.6	9.2	6.8	11.0	12.5	14.9	9.2
Civil.....	26.0	17.1	15.8	11.1	11.4	10.9	14.9	13.6	18.4	17.0	15.5	18.1
Electrical.....	18.0	18.2	21.3	15.4	16.1	20.5	17.1	15.9	21.8	21.4	17.6	17.3
Mechanical.....	21.0	22.7	15.8	28.4	18.9	21.2	21.1	16.3	26.0	28.0	30.8	23.4
Mining and Metallurgical..	8.7	6.2	2.4	4.5	1.9	2.1	1.9	1.5	2.2	3.0	2.8	2.5
Other.....	23.4	24.7	33.2	20.9	36.9	30.8	32.6	43.1	16.5	13.8	13.6	26.2
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

cent "others" are 34 per cent unclassified. Many institutions do not classify their freshmen and of course many freshmen change their minds before they become sophomores. The unclassified group declines to 4, 3, and 2 per cent respectively in the sophomore, junior, and senior years, so that in these years the distribution by classes is probably significant.

Revised Estimate of Production and Deficit of Engineering Graduates

Table V is a revision of the table under the same title which formed a part of the Compton Report. The items marked with a single star are copied directly from the table in the Compton Report. The difference between Table V and the Compton table are of course caused chiefly by the fact that the number of new students in November 1946 is so much larger than the committee anticipated. The Compton Report made separate assumptions covering the educational plans of veterans and non-veterans. In Table V both groups are treated alike, assuming that half the freshmen and sophomores will follow an accelerated program. The survival ratios for freshmen, sophomores, and juniors are the same as those used by the Compton committee. The survival ratio for seniors is the average ratio of first degrees granted in June to senior enrollment the preceding November, as taken from the SPEE reports for 1939 to 1943.

The numbers of new students to which the survival ratios are applied need a word of explanation. The number of freshmen is taken directly from Table II—namely the enrollment reported in 90 schools multiplied by 1.9. For the sophomores it is assumed that ⅓ of the indicated mortality of 46.2 per cent has taken place since last spring, and that therefore there are now on our campuses 34.4 thousand sophomores who were included in the 40.7 thousand freshmen last April. Since we have a total of 57.5 thousand sophomores this fall there must be 23.1 thousand sophomores who were not on our campuses last spring.

For juniors and seniors it is assumed that ½ of the indicated mortality has occurred since last spring. If this assumption is correct there are now on our campuses 15.4 thousand juniors and 9.8 thousand seniors who were on our campuses in April as sophomores and juniors respectively. Subtracting these numbers from the totals for these classes as shown in Table II gives the figures shown in Table V.

The rest of the computations involved in Table V follow the procedures used by the Compton committee, but lead to quite a different conclusion, because of the nearly 100 thousand students now on our campuses in excess of the number anticipated by the committee.

The table in the Compton Report indicated that the shortage of engineers in this country would be met by 1952, and that "the need for continuing engineering education at an overload level will lessen beginning with the entering freshman class in 1949." The estimates in this reexamination indicate a surplus of engineers in the United States in 1949. Actually, the over-supply may well become evident in 1948, as will be pointed out. In either event, it seems evident that the engineering colleges are facing some serious problems—not in 1949, but *now*.

TABLE V

PROJECTED PRODUCTION AND DEFICIT OF ENGINEERING GRADUATES

(Thousands of Graduates)

(Prepared by Henry H. Armsby, U. S. Office of Education, from data supplied by American Society for Engineering Education.) December 6, 1946.

Production	1946	1947	1948	1949	1950
Of those registered in April 1946					
*53.8% of the 40.7 freshmen	—	—	10.9*	11.0*	
*64.7% of the 18.7 sophomores	—	6.0*	6.1*	—	
*71.8% of the 11.4 juniors	—	8.2*	—	—	
Of the new students in November 1946					
53.8% of the 92.6 freshmen	—	—	—	24.9	24.9
64.7% of the 23.1 sophomores	—	—	7.4	7.5	
71.8% of the 18.4 juniors	—	—	13.3	—	
83.0% of the 13.6 seniors	—	11.3	—	—	
Total first degrees granted	7.0*	25.5	37.7	43.4	24.9
Less number entering graduate school	1.5*	1.0*	—	—	—
Net number available for employment	5.5*	24.5	37.7	43.4	24.9
Deficit to date	8.0*	25.5*	24.0	9.3	(−11.1)**
Annual Demand	23.0*	23.0*	23.0*	23.0*	18.0*
Total demand	31.0*	48.5	47.0	32.3	6.9
Available for employment	5.5*	24.5	37.7	43.4	24.9
Cumulative deficit to date	25.5*	24.0	9.3	(−11.1)**	(−18.0)**

* Copied from Compton Report. ** Surplus.

POSSIBLE ERRORS IN NEW ESTIMATES

Before discussing the problems arising from the present enrollment in engineering colleges, it may be well to discuss some of the many possible errors in the estimates contained in this discussion, which might easily change the small deficit estimated for 1948 into a surplus.

1. Only 147 schools were considered in deriving the factor 1.9 by which the enrollments in 90 schools were multiplied to obtain the estimates of total enrollments in engineering schools. However, very few large schools are omitted from this group, and therefore this error should be very small, and is probably offset by a small error in the SPEE figures for 1940 which was detected after completion of Table I.

2. The number of degrees granted in 1946 was estimated by the Compton committee at 7.0 thousand. The number reported by the 90 schools used in this study is 4.5 thousand. If this be multiplied by the factor of 1.9 the result is 8.6 thousand, an increase of 1.6 thousand over the committee's estimate.

3. The estimated shortage of 8 thousand engineers in 1946 should not have been used, since it was automatically included in the estimate of 90 thousand engineers neeeded by 1950.

4. The survival ratios used in the Compton Report may well be too low.

If so, the number of graduates will be larger than is indicated in Table V.

It is almost universally agreed that the veterans on our campuses are doing a better grade of work than the average pre-war student did, because of their added maturity and earnestness of purpose. They also have greater economic security, because of the provisions of the G. I. Bill. On the other hand the fact that they are older and that many of them are married will have a tendency to make the academic mortality among them increase.

The survival ratios will be affected to an even greater extent if the present pronounced trend toward engineering education, as indicated in Table I, continues. The ratios were computed from pre-war enrollment and graduation statistics, and therefore included an allowance for the students who transferred to engineering colleges from other institutions. But if present large enrollments and widespread interest in engineering continue, the number of such transfer students will increase materially.

These transfer students will still further accentuate the grave problems already facing the engineering colleges in their preparations for providing specialized instruction in the various branches of engineering to the thousands of upper class students coming out of the tremendous lower classes now on their campuses. They will also produce more graduates than are indicated in Table VI.

According to recent figures released by the Veterans' Administration, 4.8 million veterans had applied for educational benefits under Public Laws 16 and 346 up to the end of October, 1946, and applications were being received at the rate of 10 thousand per day. Four and three-tenths million had been approved for training under Public Law 346, of whom 1.8 million were actually in training of one sort or another and 0.2 million had completed the period of training allowed them under the law. Of those in training 1.1 million were enrolled in colleges and universities.

It is estimated that about 74 per cent of the veterans who receive certificates of eligibility for training definitely plan to use them, that an additional 15 per cent may perhaps use them, and that the remaining 11 per cent probably will not use them. It is not known how many veterans will ultimately apply, but if we assume that only 6 million apply, and that only 70 per cent of these will actually use their certificates, it will mean that 4.2 million veterans will be receiving training under the G. I. Bill during the nine years subsequent to the formal ending of hostilities. If present ratios hold, 2.5 million of these veterans will attend college, of whom 270 thousand will enroll in engineering.

No accurate figures are available as to the number of students whose applications for college enrollment were denied this fall because of lack of space. A recent survey of opinion of responsible educators, conducted by the U. S. Office of Education, shows that about 80 per cent of those responding were of the opinion that the number of academically qualified veterans unable to secure admission to some college this fall was either none or few enough not to constitute a serious problem, while about 20 per cent felt that the number is sufficient to be of serious concern. About the same ratios hold with respect to non-veteran high school graduates. Three-fourths of the respondents believed that the steps now being taken within the states are adequate to care for all qualified applicants seeking college admission this year.

The President's Commission on Higher Education has indicated its belief that the colleges are now handling only about half of those qualified to attend and asked itself what steps need to be taken to meet the problems implied.

How many students failed to gain admission to the college of their choice is another matter concerning which no specific information is available, but it is common knowledge that the number enrolled in temporary colleges, and the number of regular college freshmen "farmed out" by universities and colleges is large, and that in another year or two many thousands of these students will be seeking transfers to specialized divisions of colleges and universities. Among these will be large numbers of students wishing to specialize in engineering or science.

One indicator of the interest in technical and scientific education among students in non-engineering colleges is found in the calls for help in the acquisition of scientific and engineering equipment which have come to the Office of Education in Justifications of Need submitted to the field offices of the Veterans Educational Facilities Program. Here again no exact figures are available, but a hasty examination indicates that a majority of the institutions are anticipating, or already have, large increases in the number of students enrolled in courses requiring such equipment.

It seems evident that the engineering schools will be faced next year and the year after with the problem of attempting to provide for many thousands of transfer students at the sophomore and junior levels. We always have had such transfer students, but their number seems destined to increase very largely during the next few years.

5. In the estimate of the demand for engineers in this country there are also many chances for errors, some of which are pointed out in the Compton Report. Dr. Trytten, the Director of the Office of Scientific Personnel of the National Research Council, and I were responsible for the preparation of this part of the Compton Report. I have conferred with him and also with our consultant in the Bureau of Labor Statistics. The latter states that according to their statistics the country has nearly reached the theoretical "full employment" discussed in the Compton Report (disregarding current strikes). He says further that the separation rate is about as high now as it was during the war, indicating that many people are transferring from one job to another. He questions whether there is any large unfilled need for engineers at the present time in industry. He points out that a large number of people every year enter industry in engineering positions without engineering degrees, and that unless we assume that these people are to be replaced later by college graduates we must consider them as engineers. The Bureau of Labor Statistics is still engaged in their study of the need for engineers in industry, and hopes to publish it within the next few months. Thus far no figures are available from their study, but the general opinion is that their study will show a smaller need for engineers than does the Compton Report.

However, Dr. Trytten and I still feel that our estimate in the Compton Report is probably conservative, for the reasons stated in the report. We still believe that the ratios of engineers to total employment will increase as industry becomes more and more complex and turns more and more to engineering control and to engineering and

scientific research. Certainly our country is not getting the production which is needed for the good of our country and of the world. If all of the available labor force is employed the only way to increase total production is to increase the productivity of the individual laborer. This is of course quite largely an engineering task.

In our original study we estimated that after the attainment of "full employment" in 1950 the number of engineers needed merely to keep up with the growth in population and to provide for replacements in the profession would be from 10 to 12 thousand per year, or approximately the number of engineers who were being graduated from engineering colleges before the war. We mentioned the sharp increase in emphasis on research and development evidenced by the returns to the industrial questionnaire. This also is evidenced by the competition for top-flight scientists and engineers by government agencies, such as the Army, the Navy, the Joint Army-Navy Research Board, the Public Health Service, the National Bureau of Standards, the Veterans' Administration, and others.

This sharp increase in emphasis on research and development is an extremely significant factor in any determination of future needs for engineers, since it obviously points to greatly increased needs for thoroughly trained engineers and scientists. Some production jobs may perhaps be filled by mediocre engineering graduates or by competent graduates of technical institutes, but the research and development positions certainly will require a higher type of engineer and scientist.

All of these general trends lead us to believe that the Compton committee's estimates of demand for engineers in this country are more likely to be too small than too large.

Problems Facing the Engineering Colleges

It is my opinion that the foregoing estimate of the need for engineers in this country may be a little too small, but that the estimate of supply is likely to be too small by a higher percentage.

No estimate was made by the Compton committee of the demands of the devastated countries for American engineers. This demand may be heavy for a short time, but should decrease rapidly as the colleges and universities in these countries are restored to usefulness. The young men of these countries are undoubtedly seeking educational opportunites denied them during the war just as eagerly as are the young men of our own country, and it seems safe to assume that the number seeking careers in engineering and science is at least comparable to that in the United States.

In any event, it is evident that there are serious problems facing the engineering colleges *now*. I should like to outline very briefly a few of these problems as I see them, without attempting to solve them. I assume that many other problems will occur to you engineering educators who are "on the firing line." I am quite certain that the solutions must be worked out by you and your colleagues in the colleges. I believe that what you and your colleagues do about these problems may have a profound effect, not merely on engineering education, but upon all education, and upon the entire national economy.

It seems obvious to me that this country is now starting on a program of broadening the base of higher educa-

tion in much the same way the base of secondary education was broadened after World War I. A much larger percentage of our youth will attend college in the future than before the war. We have obligated ourselves as a nation to give each veteran the opportunity to secure an education. We owe it to him and to ourselves to see that he gets the kind of education he is qualified to take, and from which he can expect to emerge as a more useful citizen. We need to take account of the increased maturity of the veterans, of the fact that they are interested in public affairs and in world affairs, and of the fact that they must first of all be good citizens.

The prime function of the engineering college is to prepare men and women to understand and to aid in the technical and scientific advancement which is developing with such rapidity as to constitute a scientific and ideological revolution. For these people mere technical and scientific competence will not suffice. They must also have a vital awareness of the social, political, and economic implications of scientific and technical developments, and the ability to do something about them. We must develop a program which can produce men and women who can intelligently use the scientific method in attacking social and political problems, and can appreciate and take into account the social and political aspects of engineering and scientific problems, in short, men and women who can be "engineering statesmen."

What should be the basis for selection of students in such a program? Should the engineering colleges admit all who can meet present requirements, or should they screen their candidates more carefully for indicated ability and aptitude to profit from an engineering education? Should admission be based on paper records of credits or on mastery of necessary foundation subjects? Many believe that a well organized testing program, such as the engineering inventory, is a better indicator of success in college than a high school record several years old.

What kind of guidance should be given veterans and others as to their future occupations, and by whom? Surely a grave responsibility rests on the engineering colleges, in view of the tremendous number of present and prospective students, both qualified and unqualified, seeking to be engineers, and because of the great need of industry for really competent engineers and scientists.

The Compton Report stated that there is a need for from three to five times as many technical institute graduates as graduate engineers and indicated a short term need for about 75 thousand such people per year. The committee pointed out that "the ability of technical institutes to meet this demand is problematical." This shortage of technical institute graduates, coupled with the indicated surplus of graduate engineers, may mean that many graduate engineers will find themselves assigned to work which could be done satisfactorily by technical institute graduates. Does this call for a revision of engineering curricula and of the general administration of engineering colleges? Is it possible that society would be better served if provision were made for a certificate of proficiency at the end of two years for those who have not demonstrated their ability and their aptitude for professional engineering work? At least one engineering college is planning to give an achievement test at the end of the sophomore year to decide which students may proceed toward degrees. Certificates will be given

to others meeting certain standards in the test.

If such a program becomes general, what changes in courses and teaching methods are indicated for the work of the first two years, and what for the work of the last two years? Should the work of the first two years more nearly approach the Technical Institute type of program? Should the work of the last two (or three) years attempt to *train* for the rank and file of engineering jobs, or to *educate* for leadership in industry, teaching, and research? Should the urge of the veterans for *speed* mean they should be given ESMWT training, or should some of the techniques developed in ESMWT courses be used to revitalize and intensify engineering education?

Does the pronounced shift toward research in government and industry mean that the engineering colleges should increase their efforts to persuade their best students to continue with graduate work, for their own good and for the good of the country?

What kind of teachers do the engineering colleges need and how can they be recruited? Can programs be developed to train engineers to teach? Can industry and education work out some sort of a cooperative system for teachers as they have done so successfully for students?

What sort of relations should there be between higher education and the Federal Government? Should there be a program of Federal aid to education? If so, should it be extended to individual students or to institutions, or both? Should it be extended only during the present emergency, or permanently? If to institutions, should it be extended only to tax-supported institutions or should the privately supported tax-exempt institutions share in it? The Federal Government is now aiding individuals through the G. I. Bill and Public Law 16. Legislation has been proposed setting up a system of Federal scholarships. Institutions, both public and private, are being aided through the veterans housing program and the Veterans Educational Facilities Program in the acquisition of equipment and temporary buildings. A bill to establish a program of Federal aid in the erection of permanent buildings was debated in the last session of Congress. How far should efforts to meet an emergency be allowed to color permanent policies? In this country education has traditionally been considered a function of the States. Should the base be now broadened by making it at least partly a function of the Federal Government? If so, should Federal funds be used to partially equalize educational opportunities in the various States?

We engineering educators have long maintained that engineering education is good general education and that it forms a good foundation for almost any activity in modern life. Nevertheless we have organized our curricula with the primary objective of preparing students for engineering work. Should we now modify our present curricula, or perhaps set up new curricula, in order to give students a good general fundamental training in the basic physical sciences and a general understanding of engineering and scientific procedures? Such curricula would not be designed to prepare students to be engineers, but simply to prepare them for more intelligent citizenship in this age of science and technology. I have long maintained that one of the greatest benefits an individual can derive from an engineering or scientific education is the development within himself of the sci-

entific method of thought—the method of basing his conclusions on facts rather than on prejudices—of attempting to find out what is true and to live in accordance with the facts. I believe that this is the reason for the success graduate engineers have attained in nearly all walks of life, and I personally believe that the greatest need of the world today is for more men and women who have this scientific attitude of mind, and who will apply it to the world's problems, whether they be designing a bridge or a peace treaty, operating a railroad or a nation. Perhaps here lies the greatest opportunity for service by our engineering colleges, and their greatest challenge.

Foundry Practice for Engineering Students*

By HERBERT F. SCOBIE

Educational Assistant, American Foundrymen's Association

Any semblance between this paper and an attempt to inspire, encourage, or prod engineering colleges toward improvement in their foundry courses is purely—intentional.

Engineering colleges and industry have a producer-consumer relationship which sometimes seems to have been overlooked in the preparation or revision of curricula. Now, when colleges are revising their curricula and developing a post-war model of engineering education, is the time for industrial needs to be considered seriously.

As producers of graduate engineers, colleges should have the benefit of recommendations and suggestions from industrial plants regarding course material and objectives. In the rôle of consumer, that is, employer, of college graduates, industrial management can and will offer constructive criticism to the schools if solicited.

Cooperation between schools and industry results in more able engineering graduates and more satisfied employers. Educational institutions which consider industrial requirements when revising curricula can expect further assistance from industry, and will have the satisfaction of knowing they are fulfilling their educational function to the maximum.

Cooperation between schools and industrial groups is definitely and mutually profitable. This was shown recently when the foundry in a proposed college engineering building was redesigned and enlarged in accordance with the suggestions of the American Foundrymen's Association.

The improved foundry will have superior equipment, will enable modern foundry practice to be taught, will make more efficient use of space, and be a great credit to the university. According to a department head, the foundry, although only a part of the building project, received special consideration because the foundrymen were the only representatives of any industry to offer assistance in planning the layout and equipment.

Engineering colleges have a twofold function to perform for the foundry industry and for engineering students. All engineering students should be trained in the basic principles and applications of cast metals. In addition, those interested should be given the opportunity to train for positions in the foundry industry.

Everything used and produced requires metal castings, directly or indirectly. Spending annually more than 3 billion dollars for castings of all sizes, shapes and of some 600 alloys, manufacturers cannot afford to employ engineers who are unfamiliar with the economics of casting use, and

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*Presented at the S.P.E.E. Annual Meeting, St. Louis, June 23, 1946.

casting design. Familiarity will be gained through a good basic course in the fundamentals of modern foundry practice, and through proper attention to cast metals in other engineering courses. Modern foundry practice, you are aware, demands close cooperation between designers, patternmakers and foundrymen.

Students desiring to learn more about the foundry industry should be able to take well planned and interesting advanced courses in foundry practice, thus enabling them to prepare for a career being selected by an increasing number of young men. The foundry industry needs young men with this training.

The need for improved basic courses is demonstrated everyday in correspondence and telephone calls received at the national office of the American Foundrymen's Association.

A recent inquiry from an electrical engineer illustrates how ignorant a practicing engineer can be of up-to-date foundry products, and what a meager education he must have had in foundry practice. He requested a source of small electrical parts which, he insisted, had to be made of metal powder. Discussion brought out that the combination of properties required could be provided economically by a ferritic cast iron. The objection to a casting was that all castings contain, as he put it, "gas bubbles"!

Of course, all castings are not defective. If they were, aircraft designers, who of necessity must use low safety factors, would not specify castings of all types for aircraft construction. That foundries can and do produce castings of guaranteed quality was re-emphasized during the recent war.

Some educators are no more familiar than many engineers are with castings and casting uses. A not unusual example is the instructor of a course in internal combustion engines who argued with his better informed student that automotive piston rings are not made of cast iron. Actually only a negligible quantity of any type of piston ring is made of any other material.

The instructor in question probably would be surprised to learn that the average automobile requires about 500 pounds of cast iron. Automotive iron castings include the block, head, pistons, camshaft, crankshaft and brake-drums. Other automotive parts are produced from steel castings, malleable iron castings and the non-ferrous alloys.

Development of a good basic course in foundry practice requires, first of all, an appreciation on the part of engineering college administrators of the place of castings in our everyday life. Coupled with this must be the intent to have foundry practice taught as an engineering college subject rather than as a manual training course. Most department heads and many foundry instructors were educated at a time when a course in foundry practice consisted primarily of "pounding sand." Due to pressure of work, few have had sufficient time to study foundry developments of the past 20 years. As a result, engineering students suffer through an archaic foundry course not designed for them, or for modern needs.

Illustrations of the significance of castings to all of us, and to the economic life and development of America, are abundant. The recent war provides one example: ordnance armor programs would have bogged down had it not been for the enormous quan-

tities of cast armor provided by skilled foundrymen. Present sluggish return of the country to peacetime production is due, in part, to inability of foundries to provide castings as rapidly as other industries need them. A basic industry, the foundry must return to normal before any other industry can reach full employment and production. These facts should be kept in mind by department heads expecting to stimulate improvement of foundries under their administration.

Colleges recognizing the importance of castings set high standards for foundry instructors. Such colleges use the same care in selecting a foundry instructor that is used in selecting any other instructor. Colleges attentive to foundry industry needs devote sufficient time and thought to the problem so that the foundry instructor is not employed at the last minute. Late selection too often results in employing a man willing to take the position as foundry instructor only because he can find no other. Such an instructor is not a credit to the school, nor can he satisfactorily serve the student body or the foundry industry.

An engineering college foundry instructor should have a good educational and industrial background, as well as proved interest in castings and the foundry industry. To teach modern foundry practice, the instructor should be a graduate in metallurgy, or in chemical engineering or mechanical engineering, with electives in metallurgy. He should have had experience in several types of foundries, not only in a gray iron shop. Experience in steel and malleable foundries and in shops casting light-metal alloys, copper-base alloys, and others, is highly desirable.

The college foundry instructor should be interested in improving himself and his courses; if he does not hold an advanced degree, he should be required to work toward it.

The ultimate in foundry instructors is a professionally capable man who stimulates his students and has their respect, a man able to select and influence promising students to enter the foundry industry.

An increasing number of young men with the qualifications for, and the interest in, teaching modern foundry practice is becoming available. Some of these men have been employed by engineering colleges. Instructors with other qualifications but lacking commercial foundry experience can be aided by summer employment in foundries. This helps the foundry instructor balance his budget and gives him the industrial contact that most university staff members need.

Even the most enthusiastic foundry instructor welcomes a change and so do the students. The Wisconsin Chapter of the American Foundrymen's Association has worked out a plan with the University of Wisconsin whereby 15 one-hour lectures on foundry practice are delivered by foundrymen who are specialists in their field. The students receive first-hand information about the commercial production of castings, and have an opportunity to see the type of men engaged in the technical fields of the foundry industry. A similar program is in prospect at Marquette University.

The Wisconsin plan has proved profitable to the University. It has also demonstrated to engineering students that the foundry industry offers a place in which to apply engineering techniques, and in which the opportunity to advance is great. The latter is due to a shortage of technically

trained men in the industry, while the number of complex technical problems is inordinately large.

Once the engineering college administration and the foundry instructor have agreed that a modern course in foundry practice is to be offered, the question arises: what is a modern foundry course?

Modern foundry courses have been taught by some schools for a number of years. Schools teaching foundry practice according to current needs of the industry are recognized and encouraged by the foundry industry.

Schools with up-to-date foundry curricula were commended by N. F. Hindle * of the A. F. A. national office in a paper presented at the 50th Anniversary Meeting of S. P. E. E. held in Chicago in 1943. He indicated the necessity of teaching foundry practice as an engineering course, not as a manual training course. Stating that "the courses should cover processes and products," he added that foundry courses "should deal with the metals cast and their application, the properties available and some metallurgy."

Entitled "Castings Design and Engineering Curricula," Mr. Hindle's paper presented the current point of view regarding a general course in foundry practice. Emphasis is on castings design, cooperation between designer, patternmaker and foundryman, casting properties, and the economics of casting use. This is reasonable since all engineers use castings, whereas only a small but increasing number are concerned directly with castings production.

Molding, coremaking, melting and other foundry techniques are necessary in a general foundry course only to the extent that they enable the embryo engineer to better understand the use and design of castings.

The older system of laboratory periods only, without formal lectures, has been discarded by some engineering colleges. Foundry instructors in progressive engineering colleges devote about half the available class hours to lecturing. Emphasis is not placed on handing down a collection of traditional knowledge, but rather on the ideas behind the tradition. Instead of "know-how," interest centers on "know-why."

Typical of the modern trend in foundry instruction is the series of courses reported by Holtby and Scobie * in "A University Course in Foundry Control Methods." Described are an elementary foundry course required of mechanical engineering students and of metallurgical students, and a series of elective courses for advanced students. Taught to approximately 225 students each year (1941), the primary purpose of the elementary course is to acquaint engineering students with modern foundry practice, the possibilities and limitations of castings for engineering use, and important factors in design.

Offered at the University of Minnesota, this elementary course stressed four points:

1. The development of the foundry industry during the past two decades, and the improvement in its products.
2. The importance of control in foundry processes.

* N. F. Hindle, "Casting Design and Engineering Curricula," J. ENG. EDUC., Vol. 34, No. 7 (March 1944).

* F. Holtby and H. F. Scobie, "A University Course in Foundry Control Methods," *Trans., A. F. A.*, Vol. 49, p. 310 (1941).

3. The practical knowledge applicable in other fields.
4. The increasing opportunities for employment as a foundry engineer.

The discussion of this paper, which appears in the 1941 *Transactions of A. F. A.*, is encouraging because it illustrates a favorable trend in foundry education among some schools.

Instruction in foundry practice should be coordinated with the pattern shop, courses in other manufacturing processes, and with machine design, materials testing, materials and processes, and similar courses.

Patternmaking should be very closely integrated with the course in foundry practice. If the courses are not taught by the same instructor, or are not under the jurisdiction of one man, there should be agreement on their content to eliminate unnecessary overlapping. Important, also, is agreement on foundry and pattern terminology, pattern colors, allowances for draft, shrinkage and machining, etc.

An engineering college course in pattern practice should not stress the use of woodworking tools or attempt to make a patternmaker of the student. Elementary woodworking, that should have been learned in high school or at a home work bench, has little place in a crowded engineering curriculum. The college pattern course ought to include pattern construction for maximum moldability and economy of production, types of pattern equipment, pattern construction materials, and perhaps permanent mold construction.

Courses in which mechanical and physical properties of cast metals are discussed should be in agreement on these properties. If heat treatment of castings is taught in courses other than the one in foundry practice, the purposes, principles and results of heat treatment should be the same in all courses. If machinability of cast metals is considered in the foundry course, machinability ratings and methods of testing should be consistent with those taught in the machine shop. Principles of casting design must be the same in the foundry and machine design courses. Metallurgy of cast metals taught by the foundry instructor should agree with the teachings of the instructor in metallurgy. The industrial engineering department and the foundry department should have the same thoughts on economics of casting use, plant layout, and mechanical equipment. The high temperature chemistry of metals, refractories, fuels and fluxes should be taught in essentially the same way whether the lecturer is a foundry instructor or a teacher of chemistry.

Schools interested in developing or improving courses in foundry practice are offered the assistance of the American Foundrymen's Association. Seven national committees established for that purpose are composed of prominent foundrymen as well as educators in the field of metallurgy, engineering and foundry practice. These committees have been actively cooperating with engineering schools, making recommendations regarding course content, text books, laboratory layout and equipment, correlation with other courses, research projects, and have annually sponsored an essay contest for engineering college students. The essay contest was discontinued during the war.

Several engineering colleges have recently revised and expanded their curricula as a result of contact with

representatives of the foundry industry.

Case School of Applied Science, in cooperation with the Northeastern Ohio Chapter of A. F. A., has worked out a course expected to provide effective training for students who plan to enter the foundry business.

Massachusetts Institute of Technology has just announced the organization of a Metal Processing Laboratory under the direction of a full professor. He will have the assistance of a joint committee from the Metallurgy and Mechanical Engineering Departments.

Heading the foundry laboratory will be an associate professor. The program is expected to be flexible enough to suit the needs of any part of the foundry industry, allowing students to specialize in the mechanical, the metallurgical, or the managerial aspects of foundry work.

These examples, and others which could be cited, illustrate the trend in foundry education. Schools anticipating foundry industry needs and sympathetic with its requests often find that scholarships are established, summer employment is provided for foundry instructors and foundry students, teaching aids and casting exhibits are supplied, books are donated to engineering libraries, and equipment given for teaching and research.

Recognizing the importance of an industry producing over 20 million tons of castings annually, some engineering colleges are overhauling their foundry courses to meet present day requirements. Responding to industrial needs, department heads are reviewing foundry courses under their administration and studying ways of cooperating with casting producers. Foundry instructors are aiding by reorganizing course material to meet the need for engineering graduates with knowledge of casting properties, applications and design.

Educational committees and the 34 chapters of the American Foundrymen's Association continue to encourage and advise engineering colleges in the development of improved foundry instruction.

As a result, college graduates, adequately trained and cognizant of opportunity, are entering the industry because they recognize that the foundry is a good place in which to work.

WRITTEN DISCUSSION: W. A. Spindler, University of Michigan

John Grennan and I congratulate Mr. Scobie on a good paper on foundry instruction at the University level.

One point elicits our comment. It is inferred that patternmaking should be taught along with foundry instruction. Entirely aside from the fact that we do not have a course in patternmaking, we wonder if such a course can be justified. It would seem that the principles of patternmaking are identical with those of casting design, with the exception of draft, pattern colors and materials.

The principles of flat back construction, avoidance of loose pieces, and drawbacks, are in general closely related to casting design and can be taught with exhibits of patterns and castings, and with slides and problems in design. This is the procedure that we are using, and we also have a great variety of loose and mounted patterns that the students use in the laboratory. However, we do occasionally have our students make simple patterns and core boxes as needed, and repair patterns that are in use.

CLOSING COMMENT: Mr. Scobie

The oral discussion of this paper at the time it was presented indicated the interest which a number of engineering colleges are taking in improving a phase of engineering education which is too often neglected.

The point regarding instruction in patternmaking which has been brought up by Professor W. A. Spindler and Mr. John Grennan of the University of Michigan was intended primarily for schools which still teach patternmaking essentially as a woodworking course and separate from foundry practice. I am entirely in agreement with the idea of teaching patternmaking primarily from the casting design point of view, and heartily agree with the system of teaching pattern practice on a drawing board which is used by some schools.

General Engineering-Science

By WM. L. DE BAUFRE

Chairman, Department of Engineering Mechanics, University of Nebraska

"The time has past wherein industry hires young engineering graduates to fill its demands for technical engineering positions only. In large measure this fact is not recognized by engineering educators or by the young engineering graduates. Experience with young engineers causes industry to hire them to fit into all the functional positions of a business and the training process is depended upon to cull out from the group the relatively few technical men required. For one position in engineering there are a dozen in other divisions of activity and these positions seldom call upon their incumbents to use any depth of technical knowledge." This quotation is taken from an address at Pennsylvania State College, April 12, 1938, by L. W. W. Morrow, general manager of the fiber products division of the Corning Glass Works.

On the other hand, great advances in applications of science during and following the war will undoubtedly cause industry to call for employees more highly trained in mathematics, physics, or other science than the ordinary engineering graduate. Advanced studies in science superimposed upon a basic engineering training will be preferred for scientific research in industry for the same reason that basic engineering training has been preferred for functional positions in industry. As stated by Mr. Morrow in the above mentioned address: "Engineering knowledge, however superficial, gives the young engineer confidence and a feeling that he can act and think intelligently in the industrial environment." This is as true in scientific research as in other functional duties.

For these reasons, it is believed that a four-year curriculum in "General Engineering-Science" has a place in engineering schools. Such a curriculum should include only the most fundamental engineering courses common to all engineering groups, but with moderate emphasis upon the physical properties of materials and upon the principles of mechanics which enable these properties to be understood and applied. Such a curriculum should permit a student to obtain a knowledge of economics and business organization in preparation for a functional position in industry or to add advanced studies in mathematics, physics, or other science in preparation for scientific research in industry.

Curricula in General Engineering are now offered in about 25 engineering schools in the United States. Of these, eight have been accredited by the Engineers Council for Professional Development as follows:

University of Illinois
Iowa State College
University of Maine
Massachusetts Institute of Technology
Stevens Institute of Technology

South Dakota State School of Mines
Toledo University
Coast Guard Academy.

In spite of the limited number of curricula in General Engineering, degrees in general engineering conferred in the United States during the school-year of 1944–45 were next in number to those conferred in each of the four major branches of engineering as shown by the following table:

Branch of Engineering	First Degrees in Engineering Number	Percentage
Aeronautical	224	4.74
Agricultural	17	0.36
Architectural	43	0.91
Ceramic	13	0.27
Chemical	767	16.24
Civil	644	13.64
Electrical	854	18.08
General	364	7.71
Industrial	76	1.61
Mechanical	1371	29.03
Metallurgical	133	2.82
Mining	62	1.31
Naval Arch. and Marine	15	0.32
Petroleum	46	0.97
Unclassified	94	1.99
Total	4723	100.00

Objectives of existing curricula in General Engineering differ from school to school as shown by the following quotations from catalogs of the several institutions:

University of Illinois.—"The curriculum is intended for those who do not care to follow the more technical phases of engineering practice but who desire to ally themselves with industrial and commercial development in the fields of management, operation and construction—preparation for which is most securely founded on scientific and engineering facts and disciplines, supplemented by economic and social orientations."

Iowa State College.—"The curriculum in General Engineering is intended for students who have an interest in business or management and who also have aptitudes in engineering and plan to train themselves for some phase of business operations with technical enterprises."

University of Maine.—"This curriculum is designed primarily to permit a selected few, pre-eminently capable students the opportunity of pursuing a curriculum which gives a broad emphasis on the fundamentals of engineering and to develop themselves along lines of particular aptitudes or choice."

Massachusetts Institute of Technology.—"The course in General Engineering contains a comprehensive survey of the applications of science to the primary branches of engineering. It is designed to develop in its graduates the ability to visualize and adjust the correlated problems encountered in all fields of engineering. Standard engineering courses cannot be expected to embrace all of the technical requirements of the industrial world. The demand for new courses in special fields of engineering will constantly arise and the educational opportunity is provided in this course for their introduction and development."

The three principal objectives of General Engineering curricula may be summarized as follows:

(1) To provide a basic training in fundamentals common to the primary branches of engineering, in preparation for industrial employment in positions where such training is conducive to intelligent thought and action.

(2) To permit advanced technical studies along lines of individual aptitude or preference differing from the specialized requirements of existing engineering curricula, in preparation

for technical employment in industry more or less related to engineering.

(3) To permit nontechnical studies in economics, business organization, etc., in preparation for industrial employment in positions not classified as engineering but where basic engineering training is desirable if not essential.

In order to meet these objectives, it is evident that a General Engineering curriculum should not be administered by one of the specialized engineering departments. The departments of mechanical, electrical, civil and chemical engineering are primarily interested in advanced technical subjects peculiar to their own fields and a General Engineering curriculum should not include such specialized subjects. In fact, it has been found necessary to remove certain basic engineering courses from these departments where they were neglected as stepchildren, and to organize separate departments to teach these fundamental subjects in order to give them the care and attention they deserve.

At the University of Illinois and at the Massachusetts Institute of Technology, the General Engineering curriculum is administered by a committee. At the University of Maine, the General Engineering curriculum is administered by the Dean of the College of Engineering. At Iowa State College, there is a General Engineering Department which administers the curriculum in General Engineering.

The last mentioned procedure is apparently the best. A committee tends to lose personal interest in the students enrolled. The Dean of the College of Engineering is too busy on other matters even if his interests were not focused on his own branch of engineering. Only a separate Department of General Engineering would have the continuing interest to give students enrolled in General Engineering the personal attention they deserve.

At Iowa State College, the General Engineering Department conducts courses in engineering problems, employment methods and employee development, personnel supervision, sales engineering and cost estimating. It is believed that such courses give the General Engineering Department a bias toward industrial engineering. This would seem to be confirmed by the stated objective of the General Engineering curriculum. It is believed that a General Engineering-Science curriculum should have broader objectives.

As previously mentioned, there will apparently be a greater demand by industry in the future than in the past for men trained in science. It will be desirable for such men to have had a basic training in engineering so that scientific knowledge can be intelligently applied in the industrial environment. The General Engineering-Science curriculum would make this possible in mathematics, in physics, or in any other science.

Some schools now offer an Engineering-Physics curriculum limited to this one science. A progress report on such curricula appeared in the JOURNAL OF ENGINEERING EDUCATION for March 1946. It was concluded that such curricula generally comprise "an integrated combination of Engineering and Physics rather than a major in physics with a minor in engineering," and that "the curriculum is administered for the most part by the division of Engineering of the respective institutions."

Within the College of Engineering there are basic engineering subjects which have become as stepchildren when included within any of the major engineering departments. These are

courses in engineering drawing, in engineering mechanics and in engineering materials. By grouping such fundamental engineering subjects within a General Engineering Department, they would receive the attention they deserve as important courses in all engineering curricula.

Courses in drawing, in mechanics, and in materials are required in every engineering group of studies because these subjects are applied in all branches of engineering practice. Advancements in their application occur first in one branch of engineering practice and then in another branch. A General Engineering Department would be in touch with developments in all branches of engineering practice and would bring such advances to the attention of all engineering students. Without such a General Engineering Department, advances in one branch of engineering only are brought to the attention of students generally in that branch only.

At the St. Louis meeting of the American Society for Engineering Education in June, 1946, Dean L. E. Grinter of the Graduate School of the Illinois Institute of Technology remarked upon the departments teaching engineering mechanics. He spoke of such courses as often being included in the Civil Engineering Department. He said that engineering mechanics should probably be taught in the Aeronautical Engineering Department because the greatest advances in engineering applications of mechanics are now being made in aeronautical engineering. If engineering mechanics were taught in a General Engineering Department, advances in applications to aeronautics would be noted and would be brought to the attention of all engineering students. Of course, advances are also being made in other branches of engineering besides aeronautics, and these advances would be brought to the attention of all engineering students by a General Engineering Department.

Many new materials have become available in recent years in all branches of engineering and advances have been made in using these new materials and also in using old materials. A General Engineering Department which would include courses dealing with the physical properties of engineering materials would bring such advances to the attention of all engineering students taking such courses. By concentrating materials courses in a General Engineering Department, overlapping of subject matter and duplication of equipment would be avoided. This occurs when materials courses are divided between two or more engineering departments.

Engineering materials, engineering mechanics and engineering drawing are often treated inadequately in engineering curricula. The importance of these basic engineering subjects to the practicing engineer is not fully realized. To the young engineering graduate, the information and techniques of these fundamental engineering courses are of greater use than almost anything else learned in college.

The reason for inadequate treatment of these fundamental subjects is that faculty members with greatest authority in curricula building are primarily interested in specialized courses peculiar to their own branches of engineering. They appreciate the needs of their own specialized groups of courses but do not fully realize the needs of these fundamental subjects. In building engineering curricula, specialized groups of courses therefore receive first attention in arranging logical sequences with

sufficient time for each course in the specialized group. As a consequence, the fundamental courses in materials, mechanics and drawing, are not allowed sufficient time or a logical sequence.

Of course, establishment of a General Engineering Department to include these three groups of fundamental engineering courses would not guarantee a logical sequence of courses and sufficient time for each course. It would, however, give a spokesman for these fundamental engineering courses which they lack as stepchildren in major engineering departments.

A General Engineering Department should be more than a service department to other engineering departments. There should be a group of students in a curriculum sponsored by the General Engineering Department to give the department equal standing with other engineering departments. This would improve the morale of the staff of the General Engineering Department as well as provide advisory service for an important group of students.

It would be particularly appropriate to have a curriculum in General Engineering-Science sponsored by a department administering courses in engineering drawing, in engineering mechanics and in engineering materials, because these subjects should constitute the backbone of a General Engineering-Science curriculum. Such a curriculum should place moderate emphasis upon the physical properties of engineering materials and upon the principles of mechanics which enable these properties to be understood and applied. This emphasis might be greater than in specialized engineering curricula.

There is a trend, however, to give more time to these fundamental courses in all engineering groups as the demands of modern engineering practice are reflected back into engineering schools. The primary purpose of engineering is to provide the structures and machines which make present day civilization possible. These structures and machines are built of materials which are under stress and strain caused by the force action to which the structures and machines are subjected.

Before the structures and machines can be designed, the force action must be analyzed. Then the parts must be proportioned so that the materials employed will be stressed and strained within allowable limits. Competition in adapting structures and machines to higher loads and to greater speeds of translation and of rotation with minimum cost of materials and construction, requires more searching analyses to be made of force action and better understanding of stress and strain in selecting the materials and in proportioning the parts. Graphical methods are often preferred to mathematical computations in such analyses and working drawings must be made for construction. This requires a more thorough grasp of the fundamental subjects of materials, mechanics and drawing than now posessed by many engineering graduates.

In the General Engineering-Science curriculum, such basic training would be supplemented by courses in economics and business organization for non-engineering positions in the business of making, selling and purchasing structures and machines; or by courses in mathematics, physics, or other science for industrial positions involving the applications of science to the construction or use of structures and machines; or by specialized engineering courses in the branch of engineering in which it is desired to apply a thorough knowledge of materials and me-

chanics. This might be a very special branch of engineering with no regularly organized curriculum by reason the few students who would desire to pursue it.

The number of General Engineering students is important at present and this number will undoubtedly increase as the above facts become realized by engineering teachers and students. There will be considerable inertia to be overcome, however, in setting up curricula in General Engineering-Science to meet the objectives set forth. Staffs of the departments of specialized branches of engineering will need to be broad minded not to fear a drain of students from courses in their own departments. It will be necessary for them to realize that engineering colleges have a broader objective than training for professional engineering practice only.

It will probably be overlooked that engineering colleges are now supplying many graduates and non-graduates to positions which cannot be classified under engineering. General Engineering-Science curricula organized to provide a better training for less technical positions on the one hand and for more highly scientific positions on the other hand, will be organized only by the most broad minded engineering faculties. The attitude of Deans of Engineering and of University authorities will have much to do with organization of curricula in General Engineering-Science.

A proposed outline is appended for a General Engineering-Science curriculum to utilize courses now offered in a particular engineering school. It will usually be unnecessary to add new courses to set up such a curriculum unless present courses are inadequate in drawing, in mechanics, or in materials.

This proposed curriculum in General Engineering-Science has a core of fundamental engineering courses in drawing, mechanics and materials and contains basic engineering courses in power engineering (thermodynamics) and laboratory, electrical engineering and laboratory, and hydraulics, in addition to the science courses in mathematics, chemistry and physics usually required of all engineering students. It also contains freshmen English, 18 credits of nontechnical options including a sophomore course in business organization, and 16 credits of approved electives.

By selecting all 34 credits of nontechnical options and approved electives from courses in economics and business organization, preparation for business management is superimposed upon a basic training in engineering. The engineering courses prepare for subordinate positions in drafting, testing materials, inspecting manufactured parts and production planning, so that the graduate is prepared to take a job in industry. The courses in economics and business administration prepare for advancement to supervisory positions.

By selecting the 16 credits of approved electives in some science, such as mathematics, physics, etc., preparation for scientific duties in industry is superimposed upon a basic training in engineering. This would lead to scientific research in industry, preferably after graduate study in the science selected. A basic engineering training is preferred for such scientific work because it gives some understanding of industrial equipment and processes.

The approved electives might be selected from the branch of engineering in which it is desired to apply a more thorough knowledge of the principles of mechanics and of the physical properties of materials than obtainable in

most engineering curricula. The branch of engineering might be one for which no regular engineering curriculum is offered in the school in question.

In any case, the 18 credits of non-technical options would add breadth to the technical curriculum.

This General Engineering-Science curriculum conforms with the philosophy of "Technological Education in a Democracy" as expressed by the writer in the October, 1946, issue of the JOURNAL OF ENGINEERING EDUCATION. Each year would prepare for greater responsibility in industry as well as for more advanced study in college. The high school graduate who could spend two years only in college would be prepared for subordinate jobs in drafting, inspecting and production planning. Each additional year would add to his capacity for advancement to positions of greater responsibility in industry.

That the present time is most opportune for setting up curricula in General Engineering-Science is indicated by the following quotation from Dean L. E. Grinter of the Graduate School of the Illinois Institute of Technology (JOURNAL OF ENGINEERING EDUCATION, June, 1945):

"Through much of its history, but increasingly since 1929, engineering education has been serving two basic purposes —training for entrance into the engineering profession and education for living in a technical world."

"It is easy to fall into the mistaken belief that our students are universally destined to become professional engineers because they usually show enthusiasm for becoming members of the profession. However, if we realize that there are probably no more than 150,000 professional engineers in the United States (Government statistics indicate that only 275,000 persons claim the title), and that we will likely have an equal number of students enrolled in our engineering colleges after the war, it becomes clear that many are destined for positions in related fields. Such persons find the study of engineering vocationally helpful and intellectually stimulating."

PROPOSED GENERAL ENGINEERING-SCIENCE CURRICULUM

First Year

First Semester: Algebra 4, General Chemistry 3, English Composition 3, Engineering Drawing 2, Shop Processes 2, Engineering Orientation 1, Military Science 1.

Second Semester: Trigonometry 3, Analytical Geometry 3, General Chemistry 3, English Composition 3, Engineering Drawing 2, Surveying 2, Military Science 1.

Second Year

First Semester: Differential Calculus 3, General Physics 5, Descriptive Geometry 2, Engineering Statics 3, Shop Practice 3, Military Science 1.

Second Semester: Integral Calculus 3, General Physics 5, Sketches and Working Drawings 2, Engineering Materials 3, Introduction to Business Organization 3, Military Science 1.

Third Year

First Semester: Applied Calculus 3, Power Engineering (thermodynamics) 4, Graphic Statics of Structures and Machines 2, Engineering Dynamics 3, Approved Electives 3, Nontechnical Options 3.

Second Semester: Hydraulics 3, Power Laboratory 3, Mechanics of Materials with Laboratory 5, Approved Elective 3, Nontechnical Option 3.

Fourth Year

First Semester: Electrical Circuits 3, Advanced Dynamics or Mechanism 3, Approved Electives 5, Nontechnical Options 6.

Second Semester: Electrical Machinery 3, Electrical Laboratory 2, Advanced Mechanics of Materials or Machine Design 3, Approved Electives 5, Nontechnical Option 3, Dean's Lecture 1.

Course Requirements in Humanistic-Social Studies

By MIKE V. McENANY

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While looking over the curricula and course offerings in electrical engineering of certain universities the author became interested in comparing the requirements for a B.S. in E.E. degree as stated in the catalogues with the recommendations in the 1944 Report of the Committee on Engineering Education After the War.* In order to facilitate comparisons a chart was made showing the total number of hours devoted to each required course. This chart finally included twenty-two accredited engineering curricula. The choice of curricula to be included was based upon availability of recent catalogue issues, the oldest used being for the academic year 1944–45. This turned out to be a fairly random selection. A list of the schools included shows that large, well-known institutions are represented as well as the smaller colleges and universities; state-supported universities and colleges of mechanic arts are included along with representatives of the privately supported group.

Some of the results of this tabulation are shown in Table I, which is concerned principally with the non-technical, or humanistic-social, phase of the curriculum. In order to get a basis of comparison it was necessary to reduce the catalogue statements of course requirements to some sort of common denominator. The most appropriate unit seemed to be a semester-hour, defined, arbitrarily, as one hour per week for a period of eighteen weeks. That is, a course meeting three times per week for a semester of 18 weeks is recorded as 3 semester-hours; a course meeting three times per week for a quarter of 12 weeks is recorded as 2 semester-hours, etc. It should be pointed out that this "semester-hour" unit is intended to represent actual time spent in class and does not necessarily have any relation to course credit as determined by the registrar.

TABLE I

Subject	Semester-Hours Required			Number of Schools Requiring
	Maximum	Minimum	Median	
Freshman English	6	2	6.0	20
Business and/or Scientific English	6	1½	3.0	13
Public Speaking	3	1	2.0	10
Total English	12	2	8.0	21
Business Administration	6	2	2.8	6
Economics	12	2	3.0	21
Electives (Non-technical)	18	3	6.0	15
Foreign Language	10	6	8.0	2
History and/or Government	12	2	6.0	11
Literature and/or Philosophy	8	2	4.0	9*
Psychology	3	3	3.0	1
Sociology	8	6†	7.0	2
Total Non-technical, except English	36	3	18.0	22
Total	44	10	25.5	22

* Two of these nine schools do not require Literature or Philosophy but it is recommended that one or the other be taken as an elective.

† Strongly recommended as an elective but not required.

* The JOURNAL OF ENGINEERING EDUCATION, Vol. 34, May, 1944, pp. 591–597.

Table I shows the greatest requirement, the least, and the median among the schools requiring each subject. The last column to the right shows the number of curricula out of the 22 having one or more courses required in each subject. For instance, no school studied required more than 6 semester hours of freshman English, although several required that number. Two schools do not require any hours in freshman English, but of the 20 who do, the least requirement is 2 semester-hours. The median of 6 semester-hours was obtained using only the 20 curricula which do have a requirement in freshman English.

Before entering on a discussion of Table I, it may be well to call to mind some pertinent statements and recommendations made in the 1944 Report. The simplest means of doing so is by direct quotation.

A statement of specific purposes of engineering education in this report says, in part,

> "an understanding of values and costs, . . . the ability to read, write and speak the English language effectively, a knowledge of social and human relationships, an understanding of the duties of citizenship, an appreciation of cultural interests outside the field of engineering. . . ."

With regard to the objectives of the humanistic-social stem, the same report states:

> "they can be achieved only through a *designed sequence* of courses . . . requiring a minimum of 20 per cent of the students' educational time."

In another place,

> "Economics, sociology, government, history and psychology are sciences of human behavior and relations. . . ."

And in still another,

> "Enrich this area of work by use of whatever time may be gained . . . through higher entrance levels in . . . ordinary language skills."

Also, we find this, which seems to the present author to be an important statement:

> ". . . engineers should be counted in full proportions among groups which read books, discuss ideas, hear music, attend the theatre, appreciate works of art, sustain churches, advance philanthropy, man welfare activities, serve as trustees, and lead civic movements."

Comparison with the original will show that the above quotations from the 1944 Report are incomplete. This is not done with the intention of changing the meaning to suit the purpose, or because the omitted phrases are in any sense unimportant, but merely because they are not particularly pertinent to the present discussion.

Now let us see how the courses required, as shown in the table, appear to be chosen to accomplish these aims. The median English requirement is 6 semester-hours. If we take the average total hours required for the degree to be 130 semester-hours, then the median English requirement among these institutions amounts to 6.15 per cent of the total. This would seem to be about as much as it is desirable to allot. Whether or not it is sufficient depends, not on the number of hours, but on the quality of the instruction and on many other factors, including an important one which might be called the "cultural atmosphere" of the campus.

To eliminate the freshman English course from the engineering curriculum might appear to be a step in the wrong

direction. The Committee on Engineering Education After the War apparently did not think so. That it can be done successfully is indicated by the fact that at least two prominent state universities have done so. Surely it would be a drastic change and would be certain to meet determined opposition if the only justification we can advance for it is to gain time for other things.

On the whole, the median time allotted to non-technical subjects fits well with the recommendations of the Committee. The total non-technical median, excluding English, is about 13.85 per cent of the entire 130 semester-hours. If we include the first three subjects in the table with this, the median requirement is almost exactly the recommended 20 per cent. As has been pointed out by Boarts and Hodges,* this number is relatively unimportant. So let us inspect the results in the table more closely.

In the first place, the above figures include business administration, a course which is easily justified as important in an engineer's training but can hardly be considered a humanistic or social study. History and government might be termed basic foundation for good citizenship and a sense of civic responsibility, yet one or the other is required in only half the curricula studied. Two schools permit a choice, but not one of the 22 requires *both* history and government, a fact not shown in Table I.

If engineers are to be "counted in full proportion among groups which read books, discuss ideas . . ." then at some time during their education they should be introduced to the great books and great ideas of mankind. What better place than in a well-planned course under the direction of a scholar who is a specialist in the field? Only 7 of the 22 schools make certain of this introduction through a required course. Two others recommend it strongly, the remaining 13 apparently leaving it to chance.

Psychology and sociology seem to be largely neglected among this group. Such neglect is not at all consistent with our stated aims. Many reports indicate that some of the greatest difficulties encountered by young engineers are difficulties of adjustment to people and to social situations. It is true that there are many campus experiences outside the classroom from which students may learn to make such adjustments. Undoubtedly many do so successfully, but the many who fail to make satisfactory adjustments, easily and naturally, to the personal and social situations they meet in the early years after graduation are an indication that appreciable numbers fail to acquire during their college career the ability to analyze and solve the difficult problems of getting along with other people. The increasing social responsibility of engineers has been emphasized so often that it hardly need be repeated here. Yet meet it we must, and certainly a systematic study of psychology and sociology would be a great help, both in meeting this responsibility in later years and in solving the personal problems of early years.

Only two of the 22 curricula studied require a foreign language. Foreign language has never been generally required for engineering students. It is included here only because this is an indication that a very useful aid in acquiring appreciation of literature, the fine arts, philosophy and citizenship is being overlooked.

* JOURNAL OF ENGINEERING EDUCATION, Vol. 36, Jan., 1946, p. 342.

Required study of any phase of the fine arts is missing entirely from all of these curricula. That is an unfortunate coincidence since it is not truly representative of all curricular requirements in engineering. Some schools do have requirements including appreciation of music and art. But in a way this is representative; representative of the fact that the large body of engineers have not yet gotten around to considering appreciation of the fine arts as a necessary part of our "designed sequence of courses."

Students learn many things that are not included in the subject matter of their required courses; even many good and useful things. It is not possible to include *everything* we want our students to learn in required courses. Many of the apparent omissions are well taken care of in extra-curricular activities such as student branches of professional societies, or in elective courses. In some cases, departmental recommendation for the election of certain courses is so strong as to amount to requirement, although it might be better to be more honest and say that enrollment in such courses is required. However, when enrollment in courses such as literature, philosophy, fine arts, is truly elective on the part of the students, there can be no assurance that all, or even an appreciable portion, of our graduates will have adequate foundation in the fundamentals of the humanistic-social studies. Students are too prone to choose courses on the basis of the reputation (among fellow students) of the professor, and it is human nature to avoid as much as possible that about which we know nothing. To learn to rise above this tendency and seek out the unknown is part of the educative process, best learned by meeting new situations often enough to lose our fear of the experience. The subject about which a student knows nothing is very often the one he needs most to study.

If the elimination of electives is considered undesirable, the loss must be balanced by our gain in progress toward our stated purposes. If we cannot teach our students everything they need to know in required courses, at least we can require a sufficient variety of courses to be sure that they have the abiding interests and adequate foundations which will enable them to continue their educational growth throughout life, in the directions which our collective experience has found desirable, and in fact, almost necessary, to the successful engineer.

The descriptions of curricula and courses found in catalogues give a very incomplete picture of the training being given in any school. The median numbers of semester-hours shown in Table I have very little significance in themselves; the median is so seldom the actual number required in any of the curricula. However, some small part of the total picture of engineering education can be gained from these data.

The curricula upon which this study is based were picked at random, as has been previously mentioned. This is not a selected sampling and so cannot be considered truly representative of the general practice, although it should approximate it to some degree. Under these circumstances, probably the most significant facts are the omissions, or deficiencies, found. Some attempt has been made here to emphasize those omissions.

The required course is our best-controlled and most reliable means of making sure that our graduates have the foundations of a well-rounded edu-

cation. How it is used must be determined for each institution on the basis of the problems and situations peculiar to each; however, if we do not use it to the best advantage in achieving our objectives, then we must either try to set up other agencies to accomplish the purpose or more carefully control presently existing agencies such as extracurricular activities. The other choice is to leave the outcome entirely to chance. None of these alternatives appears very desirable.

While the results of this study do not present concrete facts useful to any college or university, they do constitute another strong argument in favor of a re-survey and critical scrutiny in every accredited engineering college of the means employed to accomplish the adopted aims and purposes of the humanistic-social stem of engineering education.

On the whole the trend seems to be good. The people most directly concerned with engineering education are working at the problems of improvement and seriously trying to find solutions. But there is much to be done and numerous changes to be made before many of us can say that we have a well-planned educational program with definite objectives and reasonable assurance that they are being achieved. Before these changes will be made, a large majority of the members of the engineering profession, and particularly of engineering faculties, must appreciate the great importance to the future of the profession and of civilization of a program which will accomplish *all* of the stated aims of engineering education.

The Teaching of Statistics for Quality Control *

By LLOYD A. KNOWLER

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During this time of revision, reconversion and curriculum changes, it is only natural that we as educators and as representatives of industry focus our attention on that phase of our course of study commonly referred to as *quality control by statistical methods.* It is particularly fitting for this discussion to be taken up at a meeting of the American Society for Engineering Education because of your interest in new developments and of your desire to promote sound education in engineering.

The primary purposes of this paper are to review briefly the history of statistical quality control, to indicate the scope of quality control courses, to refer to some needs of industry which the writer has encountered, to mention some of the savings involved, and to make some suggestions which the colleges and universities might follow to aid in the solution of the problems by presenting information to our students to use in their work upon securing positions after graduation. This is not an easy task. In fact, each of the points deserves much more attention than can be provided in one discussion. We can only hope to obtain somewhat of an overall picture.

A relatively new approach to quality control has been through a more intensive use of statistics; not statistics by itself but with the cooperation of management, engineers, and other persons concerned. Only during the past few years have many industries made much use of statistical quality control. Probably not nearly as many industries made use of it prior to the war as one might be led to believe in listening to certain reports today. During the war it became necessary for industries to manufacture goods although hampered by a lack of materials and an inadequate number of trained personnel and to produce those goods to meet certain specifications without much loss of time. It was desirable to get more information out of less data. It was necessary to design experiments so the data obtained would be meaningful. It was found that statistical procedures were very beneficial.

The Office of Production Research and Development of the War Production Board cooperated with educational institutions in giving *short, intensive courses* in quality control by statistical methods. For the most part these courses were eight days in length. The first day was usually designed as a special session for executives and trainees while the following seven days consisted of conferences, lectures, and laboratory periods. A large number of the trainees were individuals who had a great deal of responsibility in

* Presented at joint meeting of the Engineering Economy and Industrial Engineering Divisions, S.P.E.E., St. Louis, June 20–23, 1946.

their organization. This was especially true during the later courses when management, including engineers, realized more fully the value to them and to their organization. Each course was usually followed by four to six one-day follow up sessions at intervals of approximately one month. These follow up sessions proved to be very much worth while—in fact, in many cases these follow up sessions still continue. Questions which arose in practice are reviewed at these meetings; additional laboratory exercises are considered; and new developments are presented. Thirty-four such intensive courses were given throughout the United States. Over 3,600 industrial representatives attended the special one-day sessions for executives, of which number nearly 1,900 completed the entire course. We, at the University of Iowa, were fortunate in being able to cooperate by giving two of these courses.

Last November we sponsored a ten day course in Quality Control by Statistical Methods. Arrangements are being made for a fourth one October 15–25 of this year.

A few educational institutions in the industrial areas have provided *part time courses,* largely in the evening, which has helped to supply the need for engineers who are trained in this area.

A number of plants have conducted *in-plant training courses;* some formally, some informally. In fact, it is not unusual for a trainee who has taken an intensive course or a part time course to give an in-plant training course upon his return to the plant. This is to be encouraged. The trainee benefits by presenting his views to others. When done in a cooperative manner, it tends to build the confidence of others in him.

The reports of industrial representatives who have taken these courses have been *spectacular.* To mention a few of those with whom the writer has been in contact either directly or indirectly: one concern estimated a saving of several hundred dollars per week by making the contents of packages more uniform. This figure, incidentally, was given by an independent source, and not by the individual interested in promoting the procedures in his company. Another concern had ordered machinery to the extent of one hundred thousand dollars. By statistical procedures they were able to determine the lack of a need for such machinery. The order was cancelled. Recently a representative of another concern told me that through investigation of points out of control the *engineers took action,* made what were not major adjustments and the processes which resulted are estimated to mean two hundred and fifty thousand dollars to the company. Another company reduced scrap and rework from over nine per cent to nearly two per cent. A large clerical office made a reduction of from thirty to forty per cent in the number of errors within a year's time. Another company which produced small parts inspected millions of pieces each year prior to the installation of some sampling procedures through statistical methods. At the present time it is only a small proportion which is examined. They maintain that a better product results because they now know where and when to look for defective material, and it is well recognized that no need exists for sorting good materials. These illustrations are for the most part taken from large companies, but in each case one should realize that a particular solution is applied to one unit of the company. *A*

small section of a large unit or company would in itself represent a small concern. In fact, the savings are probably of greater proportion in small concerns than in the large ones. One small plant of five or six employees reported a savings of approximately fifty per cent within a short time.

In each of these examples statistical procedures by themselves did not cause the savings. In fact, it was the cooperation of the engineering departments which enabled changes, for the most part minor ones, to be made so that the savings could result. Statistical procedures pointed to the place for action!

In the first of the training courses considerable emphasis was given to inspection. A great deal was mentioned concerning the lowering of inspection costs. In the middle west we did not follow this pattern. In fact, in many cases the inspection cost may have risen at first. *Our emphasis has been upon better quality.* Actually we have obtained better production at less cost. We emphasize the need to control the quality while the product is being made and at the time it is being made. We make no attempt to produce quality by sorting the bad from the good, or the good from the bad, after it has been made. Consequently our emphasis has been to a large extent upon production developing means whereby attention could be focused on the process when things are not going right and insisting that changes not be made when things are going right. At the present time a great deal of use is being made of quality control by statistical methods in design and specification. Engineers are beginning to ask what the machine will do rather than setting some specification at what they think should be done. Will the machine meet the tolerance? What is the smallest tolerance which can be met economically? Engineers have discovered that it is uneconomical to require close tolerances which the machines are unable to meet. It is uneconomical to have 100 per cent inspection or sorting in many cases. Furthermore, they are beginning to realize that the man in the shop recognizes that variation between parts exists, and consequently tolerances must be made so as to meet the variation or it is necessary to change a method, a process, and have 100 per cent sorting. This has gradually brought about additional problems for research and development. In fact, most of the more difficult problems which the writer has encountered have been in those plants where not long ago the engineer and/or the management were certain that little or no theory was involved in the practical applications. This attitude has changed. It is now recognized that theory and practice go hand in hand—probably the same. What works in practice has a reason, that reason is the theory. What was thought to be highly theoretical a few years ago is highly practical today—industry is beginning to realize a greater need for knowing the reasons.

Partially from a demand following various types of courses, and possibly because of industry itself a society entitled THE AMERICAN SOCIETY FOR QUALITY CONTROL has been formed during the past few months. At our formation meeting in New York last February we had seventeen or eighteen persons who officially represented nearly 1,200 members. A journal entitled *Industrial Quality Control* is supported by the Society. Its Editorial Board consists of people in colleges and in industry. The whole undertaking entails close cooperation between the

colleges and industry, with industry carrying its full share of the load.

Our immediate question, the one before us now, refers to what the colleges and universities can do. The short intensive courses are helpful. It might be desirable for a few institutions to continue the practice for at least a few years. It is doubtful, however, if it is advisable for a great number of educational institutions to promote this practice. Much time and effort is necessary to do an effective job. Industry demands thoroughness and unless several candidates are in attendance the right kind of spirit is not attained. Some evening courses are helpful for those schools located in industrial centers provided the right type of personnel is available to conduct the course. No doubt companies will continue to conduct in-plant training courses which will probably continue to be rather limited in scope and designed only for a particular job.

These are aids and worthwhile ones. They do not reach the *fundamental problem* of training quality control engineers or of training engineers to make use of quality control by statistical methods. *This should be done at the College or University while the individual is securing an engineering education.*

At one time many people thought quality control by statistical methods should probably be a course in mechanical engineering and in mechanical engineering alone. A little later some thought it should be in industrial engineering and in industrial engineering alone. Others refer to it as a requirement for chemical engineering. In fact, it has been recommended that it be put into about every branch of engineering according to the interest of the persons who happen to make the suggestions. As in determining the place for a quality control organization in an industrial plant, much depends upon the personnel available. The course must be accessible to the student—*not merely possible for him to register.* Maybe the course should be put into the general engineering program.

It would be my suggestion that it be of *at least three semester hours'* length given during the senior or graduate year. Furthermore, it would be my suggestion that, at least for the present, it be made an elective course. It is very likely that we could better meet the demands of industry by having *an elective course* where the majority of the students are interested rather than by having a required course where everyone would take the course but some would not be enthusiastic. Giving the course during the senior or graduate year has the advantage that the student has had the benefit of at least two or three years of mathematics, has had training in engineering methods, and is interested in securing a position in the near future. By so doing the teacher could draw upon the engineering knowledge of the student and consider problems which would otherwise be rather difficult if not impossible for them to understand. The idea could be better brought out that for greatest benefits it is *necessary to draw upon an entire program*—not a single phase.

In fact, it has been reported that some fifty colleges and universities are going to give such a course this fall. Such a report disturbs me somewhat in that it is possible for the universities to do as industry has tended to do—upon making one or two successful applications of quality control by statistical methods, a request is made for

"two or three carloads" to be delivered immediately. We do want to go only as rapidly as possible and still be on sound principles.

It is important that the person in charge of the course understand pretty clearly the fundamental principles underlying the theory to be applied. The writer, in attending many follow up sessions, has heard answers given to questions long before he could even understand the basic problem; answers to problems in which the writer feels to be somewhat qualified and where it has been thought that the person answering the question had little training and probably no practical work. Had such answers been accepted—and in many cases they would have been, had not someone requested more information—disastrous results would have been obtained. The blame would have been put upon the statistical methods while actually it was the fault of the person who answered the question.

Furthermore, the individual in charge of the course must be able to cooperate with other units involved. That is one of the basic principles we have always stressed in discussions with our trainees concerning the installation of quality control in their plants. The individual who makes an installation cannot be a lone eagle. In addition to having a knowledge of the problems of management, he must work with other individuals in the plant. The program is not going to succeed because of only one person. Those on the line, the men at the machine, the girls in the aisle, the clerical help in the office, are the ones who are going to make it work. The quality control engineer must be willing to work with people, explain their problems, admit he does not know all the answers, give credit to his associates, and *encourage them* if success is to be assured. Should a would-be quality control engineer be interested only in hanging on to the coat tail of a vice-president, maybe some other position in the plant would be a better one for him in so far as quality control is concerned. The quality control engineer must work with *management and employees*—he must be a high grade individual and one who has responsibility.

Suggestions have been made to place quality control by statistical methods in an area other than engineering. Some basis exists for this suggestion. Professions other than engineering are becoming interested. The accounting profession is interested, probably from a view of budgetary control. The association of science and mathematics teachers of the high schools is interested, probably from a view of future vocation. Certain clerical offices are interested, possibly in its application to the elimination of error hazards.

However, the greatest progress has been made in the engineering profession—*it is here that many opportunities lie*. Many of us sincerely feel that the surface has not been scratched. It is in the engineering colleges that future engineers are reached, it is here we have young men (and women) trained in a scientific profession where applications are needed, it is here we look for new developments in our scientific world. It is up to our engineering colleges to be certain that our graduates have had access to this new development which promises to be a permanent one.

College and Professional Registration Examinations*

By H. T. PERSON

President, National Council of State Boards of Engineering Examiners

A. Development of Examining by State Registration Boards

A brief review of the development and growth of the procedure and practice of examining candidates for registration as Engineers by State Boards is, I believe, germane to the question of the relationship of college examinations to those given candidates for registration as Professional Engineers.

The first registration law for Engineers was adopted by Wyoming in 1907. During the next twenty years, or by 1927, twenty-one states had Engineering Registration Statutes. Today 47 states, Alaska, Hawaii, the Philippine Islands and Puerto Rico have Engineering Registration laws. Only one state (Montana) does not have an Engineers registration law.

During the first 20 years of the history of Engineering Registration Laws, in fact up to about 1930, there was wide variance in the methods of examining candidates for registration by the various State Boards. There was little, if any, uniformity in the type, content and degree of difficulty of the examinations given by the various State Boards. In 1927 less than one-third of the Boards required all candidates to take a technical examination. Many State Boards did not require graduates of Engineering Colleges to take an examination. Up to this time many State Boards undoubtedly gave examinations that were more or less perfunctory and didn't contribute much, if anything, toward determining whether or not the candidate was qualified to practice professional engineering. The length of the examinations given by the Boards that used written examinations varied from ½ to 5 days.

In 1929 the National Council of State Boards of Engineering Examiners, which was organized in 1925, appointed its first Committee to study the question of examinations. Since that time Committees of the N.C.S.B.E.E. have been working continuously on various phases of examinations, both written and oral.

In 1931 N.C.S.B.E.E. Committee on Examinations made the first comprehensive report on engineering registration examinations. Some of the more important recommendations of the 1931 Committee which were approved by the Council are:

1. Written examinations should be maintained as a standard requirement for the registration of professional engineers. Exemptions should be granted only in exceptional cases of obvious outstanding educational and professional qualifications.

* Presented at the 54th annual meeting, S.P.E.E., Educational Methods, St. Louis, June 20–23, 1946.

2. Exemption from examinations of engineering college graduates is not favored.
3. The major part, or about ¾ of the written examination, should be uniform for all applicants for registration and the remaining, or about ¼, may be differentiated for the various major branches of Engineering; such as Civil, Mechanical, Electrical, Mining, etc.
4. Written examinations should be at least two (2) days long, and preferably three (3) days.
5. Oral examinations should be provided to supplement the written examinations in special cases.

The present practice of the State Boards of Engineering Examiners may be summarized about as follows:

1. All Boards use written examinations for some applicants. Most State Boards require some type of written examination for all young applicants. A few Boards still exempt graduates of approved engineering colleges from all examinations.
2. The length of the written examinations given by the different State Boards varies from one to four days—with a majority of the Boards favoring and using a two day examination.
3. The content, type and degree of difficulty of the written examinations given by the different State Boards are much more uniform today than it was 20 or even 15 years ago. Probably a majority of the Boards give all applicants for registration a uniform one day examination covering mathematics, applied sciences, mechanics, statics and engineering materials—and a one day differentiated examination covering the branch of engineering (Civil, Electrical, Mechanical, etc.) in which the applicant is particularly interested.
4. Very few Boards, and possibly only one, give all applicants an examination covering the subjects of economics, engineering law and professional ethics. The majority of the Boards, if they examine the applicant at all in these fields, do it as part of the one day differentiated examination covering the applicant's particular field of engineering.
5. A number of Boards exempt graduates of approved engineering colleges from examinations in the fundamentals—such as would be covered in the one day uniform examination for all applicants mentioned under (3) above.
6. Today, I believe only 4 and possibly 5 State Boards require all applicants to take an oral examination. About one quarter of the Boards require oral examinations of some candidates.

The present status and practice of the State Boards in connection with the Engineer-in-Training program should, I believe, be of interest to engineering educators. The latest available data show that the Engineer-in-Training program has been started by at least six State Boards (New York, Ohio, Iowa, Minnesota and Missouri). The matter of getting the program under way is under consideration by at least fifteen additional State Boards. I believe that most, if not all, the six State Boards that have started the Enginer-in-Training program require a

written examination of all applicants for certification as Engineers-in-Training.

A survey made in 1944 by the N.C.S.B.E.E.'s Committee on Written Examinations indicated that a large majority of State Boards favored the use of a written examination as a means of determining an applicant's fitness for certification as an Engineer-in-Training. A few State Boards felt that graduates of approved Engineering Colleges should be exempted from the written examination. The N.C.S.B.E.E.'s Committee was of the opinion that a written examination about 8 hours long with emphasis on such fundamental subjects as mathematics, physics, and mechanics was desirable for all applicants for certification as Engineers-in-Training.

B. Types and Objectives—College and Registration Examination

To my knowledge no American engineering school gives a comprehensive examination to determine if a student is qualified for a degree in Engineering. The College examinations are given piecemeal over 8 semesters or 12 quarters and are given to determine if the student is doing satisfactory or passing work in a particular subject such as calculus, mechanics or reinforced concrete design. The examination covers material in a single course which the student has been studying for 12 or 16 weeks at the longest, and is given at the time he is studying the course. In other words the primary objective of college examinations is to test a student's knowledge of a single or part of a single course at the time he is or has just completed studying that course.

The purpose or objective of an examination given to an applicant for registration should be to test or measure fairly and accurately his fitness or lack of fitness for professional engineering practice. The time element does not permit testing an applicant for registration on everything that he should know. Examinations must be carefully prepared to give reliable results. It is desirable that the examination should, in some way, test the applicant's engineering sense and ability. Since the essential objective of the examination should be to determine the applicant's qualification as an engineer and not as a specialist, the examination should be broad in scope and basic rather than specialized.

Careful preparation of college examinations, although it certainly is desirable, is not as important as the careful planning and preparation of professional registration examinations. Registration examinations must be skillful sampling to give reliable results. Since much more time is devoted to examinations in college courses (probably between 200 and 300 hours during a 4 year college career) then would be possible in registration examinations, careful preparation of the examinations is not as essential to obtaining reliable results.

C. Registration Examinations for College Graduates

As was noted earlier a few State Boards still exempt graduates of approved Engineering Colleges from any examination. Some State Boards exempt engineering graduates from the examination in fundamentals such as mathematics, applied science and mechanics, but require them to take an examination in a particular branch of Engineering (Civil, Electrical, Mechanical, etc.).

After 12 years as a Member of a Board of Enginering Examiners, I am a strong advocate of giving written examinations to all young applicants for registration. The only applicants the Wyoming Board now exempts from a written examination are those of nationally recognized professional status, those certified by the National Bureau of Engineering Registration and those registered in other States by examination.

I appreciate that advocates of exempting graduates of approved engineering colleges from written examinations, when they apply for registration as professional engineers, make the claim that it is useless to duplicate examining that has already been done by the engineering colleges. In the first place the Engineering Colleges have not given the applicant a comprehensive examination, and the examining done by a State Board should certainly not be duplication of the piecemeal examining by subjects done by the colleges. Secondly, most State Engineering Registration laws require an applicant to have 4 years of engineering experience of a character satisfactory to the Board. The only reliable way to measure if the applicant has grown technically during the four years as a result of this engineering experience is to examine him—and the most reliable and satisfactory method of examining him is by a written examination. I think it has been the experience of every State Board that does not exempt graduates of approved engineering colleges from written examinations, that it definitely would be an unsound policy to do so. The State Boards that require a written examination for engineering school graduates have found that engineering college graduates do fail the examinations. A number of these fail repeatedly. I am sure that if all Boards followed the policy of exempting engineering college graduates from written examinations—a goodly number of applicants would be registered engineers today, who are not.

Furthermore I believe the prospect of taking an examination for registration is definitely an inducement to the young engineer for continued study and professional growth.

In regard to the Engineers-in-Training who are certified at the time of graduation—the matter of requiring a written examination might be different. Personally, I don't believe they should be exempted from the written examination. I think the experience of those State Boards, that require the applicant for certification as Engineer-in-Training, to take a written examination shows rather conclusively that exemption from the written examination is an unsound policy. When engineering colleges require a comprehensive examination over the four years of college work as a prerequisite to obtaining an engineering degree —then and only then should the State Boards exempt college graduates from the written examinations.

D. Oral Examinations

It has been suggested a number of times that the State Boards should exempt engineering college graduates from written examinations, and use oral examinations in lieu of the written examinations. Oral examinations have not been used either extensively or effectively by Boards of Engineering Examiners as a means of measuring an applicant's fitness for registration. This indefinite and ineffective use of the oral examination is due pri-

marily to the inherent disadvantages or weakness of the oral examination.

The most critical weakness of the oral examination is its unreliability as a measuring device. Studies have shown that even experienced oral examiners will rate a candidate widely different on the same oral examination. The reliability of the results obtained from the members of a Board of Engineering Examiners, with little if any experience in oral examinations, would certainly be questionable.

Standardization is difficult, if not impossible, to obtain in oral examinations. Anyone who has sat on oral examinations realizes and appreciates this weakness. It would be unusual indeed if two oral examinations were of the same degree of difficulty. Some oral examinations are well conducted and are thorough in every respect. More are poorly conducted and extremely superficial.

Oral examinations, and especially those conducted by inexperienced examiners, do not cover an adequate sampling of questions. The sampling of questions varies widely for different applicants examined by the same group. Variations between different Boards would be even still greater.

Oral examinations are uneconomical from the standpoint of time. To assure any degree of reliability from an oral examination requires that a number of examiners rate the candidate on the oral examination. This means using more of Board Members' time than would be required for written examinations. In fact, the time element makes oral examinations for all candidates absolutely impractical for any State Board that handles a large number of applicants each year.

The oral examination has some advantages that make it a desirable measuring tool in some instances. The oral examination makes it possible to individualize the examination of an applicant. Also the critical examiner can make the oral examination more critical and searching than a written examination. It gives the opportunity to observe how the applicant thinks—how he arrives at his conclusion. In other words it gives the opportunity to closely examine his mind.

If the oral examinations are to be used effectively in measuring fitness for registration, they cannot be a "hit and miss" proposition. They need to be given the same serious consideration that is given a written examination. Examiners sitting on oral examinations should prepare at least a few well selected questions in advance. This results in a more adequate sampling of questions, and some questions of sufficient difficulty so that the answers given by the candidate would be some measure of his fitness for registration. Also advance preparation would result in more uniformity in the difficulty of the oral examination given to various candidates.

The method of conducting the oral examinations should be planned in advance. Oral examinations conducted as "hit and miss" and "spur of the moment" propositions generally result in superficiality, and give little real information on a candidate's fitness for registration. The questioning should be guided in accordance with previously devised plans. The examiners must maintain control of the examination and must avoid letting the candidate maneuver the examination to his liking.

Most candidates are scored in oral examinations from "general impressions." "General impressions" are highly unreliable. With questions pre-

pared in advance, it would be possible to rate each question as to its degree of difficulty. Each examiner should score the candidate on each question. The method of scoring a candidate will give much more reliable results than scoring from "general impressions."

In closing I admit I have stayed away most of the time from the subject—"Relationship of College Examinations to Examinations for Professional Engineers"—which was assigned to me. Frankly under present conditions I don't see much, if any, relationship. When engineering colleges give comprehensive examinations covering the four years of college work —there is bound to result a much closer relationship—and when that time comes State Boards could exempt engineering college graduates from examinations in the fundamentals. Also when that time comes the engineering college graduate could be certified as an "Engineer-in-Training" without any examination.

Cooperation Between Departments of Physics and Mechanics in Engineering Colleges

By R. Z. WILLIAMS

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The teaching of mechanics to engineering students is so affected by the students' previous courses in mathematics and general physics that the usual methods of teaching those broad subjects must be considered in discussing the teaching of mechanics.

Instruction in arithmetic is started while the student is in the lower grades and is still a child. It is continued slowly through grade school, the youngster growing-up with arithmetic and using it in his life from day to day. Upon entrance to high-school he is introduced to algebra and plane geometry. He may take more than one course in algebra during his high-school years, and he may even take trigonometry and solid geometry. Thus he may arrive at an engineering college with years of mathematics behind him. He is no longer a child, and he is ready for the intensive mathematical training that he is about to receive. In rapid succession he studies college algebra, trigonometry, analytic geometry, differential calculus, and integral calculus. These courses are usually fairly rigorous with the standards reasonably high, and properly so since the young man is being trained for a profession in which mathematics cannot be avoided.

In the meantime, what has been this young man's experience with physics? During his years in grade school and high-school he became conscious of certain laws of physics through the events of his daily life, but he had no formal instruction in the subject until late in his high-school career. His high-school course in physics was necessarily very elementary since it was the student's first contact with an extremely broad science. Perhaps a few simple problems were solved, but most of the time was devoted to the development of an understanding of some of the simpler laws of physics. Thereafter, the subject was laid aside, and its study was probably not resumed until the second year in college. The student's college course in physics probably consisted of two semesters of lectures and laboratory taken concurrently with differential and integral calculus. It probably covered the entire field of physics in a very general way, and included the solution of a moderate number of problems. The amount of time allowed for the course was probably small enough to preclude leisurely study since the various subdivisions such as mechanics, heat, light, sound, electricity, and magnetism all had to be given due emphasis. Nevertheless, the student emerged with a reasonably good working knowledge of the laws of physics, and with some problem-solving ability.

His training in mathematics had

given him the ability to solve the equations which his training in physics had taught him to formulate, and it remained for him to take the special courses in the various subdivisions mentioned before. These courses included statics, dynamics, mechanics of materials, thermodynamics, fluid mechanics, etc. As a group, these courses served as a sort of bridge from the purely scientific view of the physicist and mathematician to the semi-scientific view of the engineer. More and more practical problems were introduced, each calling for its own modification of the theory, and each calling for its own simplification of the pure mathematics involved. The laws of physics were applied to real problems, and the solutions were obtained through application of mathematics. Of course, since the student's formal instruction in physics had been rather brief, as described before, it was necessary to study more thoroughly those topics which had been introduced previously and to consider other topics that had not been introduced. On the other hand, it was assumed that the years of training in mathematics had been sufficient to permit solution of the problems encountered, so that additional instruction in mathematics was not considered essential even though it might be desirable. Then, finally, after completion of these transitional courses, the student passed on to the strictly professional courses in whatever curricula he happened to be studying.

In view of the process just described, the teacher of engineering mechanics can decide just what training he expects his students to have had in physics and mathematics. It is reasonable for him to expect excellent proficiency in arithmetic, and in the fundamentals of plane geometry, algebra, and trigonometry. He should expect some trouble when the more or less unusual geometric theorems are encountered and when more advanced algebra and trigonometry are required. The average student can be relied upon to use the simpler phases of analytic geometry and calculus, but he will need encouragement and assistance in anything beyond that. However, instructors can and should feel that their sudents are capable of following explanations and demonstrations of problems involving any mathematics included through the course in integral calculus. For the instructor to avoid such free use of mathematics is to encourage the student to do likewise when he finds it painful to retrace the lines of thought he used while studying mathematics. Such evasion will not build engineers, nor will it build character.

Now, what can the teacher of engineering mechanics expect his students to know about physics? He can expect them to have been introduced to the fundamental quantities of force, time, and length. They will know the characteristics of vector and scalar quantities, and will understand what resultants, equilibrants, and components are. They will understand the difference in algebraic and graphic solutions for resultants, but their study will have been limited to coplanar concurrent and coplanar parallel force systems. The fundamental relations between acceleration, velocity, and displacement of particles having rectilinear and circular motions will have been studied, but particles having general curvilinear motion will not have been considered. They will have considered Newton's Laws of Motion, not too thoroughly, however, and will have solved problems involving bodies having pure translatory and rotational mo-

tion. They will not have considered general plane motion of bodies. Their study of bodies in equilibrium will probably have been limited to bodies acted upon by coplanar concurrent or coplanar parallel force systems. There will have been an introduction to work, energy, impact, momentum, elasticity, stresses and strains in elastic bodies, and liquids and gases at rest and in motion. At least a few problems will have been solved in each of these topics. Considered as a whole, their knowledge should be expected to consist of a collection of sound ideas concerning the most common and fundamental laws of physics, but they should not be expected to have much problem-solving ability, nor should their knowledge of the various laws of physics be expected to go beyond the simpler ones.

On the average, students beginning their first course in engineering mechanics satisfy the expectations just described. Probably they impress their instructors just as favorably with their knowledge of physics and mathematics as the students leaving the mechanics department impress their instructors in subsequent courses. Nevertheless, there are certain deficiencies and erroneous ideas that seem to be rather common among students studying engineering mechanics, and it is possible that frank discussion among us teachers might help to remedy the situation. It is with that thought that the subsequent observations are made.

Among students studying engineering mechanics, there is a strong tendency to stand in awe of calculus. Too many students feel that it is unfair for an instructor in mechanics to require them to solve an occasional problem by calculus. They are often willing to memorize many formulae and to work through tedious arithmetic solutions just to avoid using calculus. That they are sometimes aided and abetted in this attitude is indicated by the occasional textbook that has been written without use of calculus. It is admitted that the student cannot have completed his courses in calculus prior to his study of physics. Instead he usually takes calculus and physics simultaneously. But why avoid using calculus? Would it not be better to apply it at every opportunity in a physics course?

Too many students exhibit extreme carelessness in simple algebraic manipulations. Their handling of algebraic signs is a case in point, and again they sometimes receive encouragement. In instance, in applying the Law of Cosines a "Modified Law of Cosines" is sometimes recommended for those cases where the included angle is greater than 90°. This "Modified Law of Cosines" simply changes the negative sign in the last term of the conventional Law of Cosines so that the student need not be bothered by a negative cosine function. Of course it works, but why avoid the fact that cosine functions are sometimes negative?

The writer feels that we teachers may have been guilty of over-simplification. Not long ago, he gave two classes in statics very similar examinations, each containing a crane type framework. In one of these examinations, all dimensions were given horizontally and vertically while in the other one, all dimensions were given along the members. This meant that all lever arms in this last examination had to be calculated by trigonometry and geometry. There was a 30 point difference in the average grade of the two classes, the examination requiring trigonometry and geometry resulting in the lower grades. Would it be a good idea to give the dimensions of our problems so that some

trigonometry and plane geometry have to be used? Apparently the students need to be forced into refreshing their memories.

Many students coming from their first course in physics have paid too little attention to the characteristics of forces. They may know that a force has magnitude, direction, and location, but their study has been mainly on force systems in which location of the forces presented no problem so that only magnitude and direction were found. It should be emphasized that the stability of many structures depends upon the location of the resultant ce on that structure. It should also emphasized that, while the Principle of Transmissibility is correct when considering the motion effect of forces, it is not valid when considering the deformation, stress, and strain in bodies.

The study of mechanics involves the conception of free-body diagrams to such a great extent that this idea should be presented during the course in physics. The student should be taught to isolate the body being considered, to show a force acting on that body at every point at which some other object touched it, and to show the gravitational force. He should be made to understand that the forces shown on the free-body diagram will cause the body to have exactly the same motion as the body had in its normal position. He should learn that these forces all act simultaneously and therefore cannot be treated separately, and that the motion fixes the forces, or that the forces fix the motion. If students could begin their course in statics with a clear understanding of free-body diagrams, considerable time could be saved.

To the student beginning a study of the motion of a particle, acceleration is a mysterious thing. He is troubled by such questions as how there can be an acceleration without a velocity, and how the magnitude of a velocity can remain unchanged even though there is an acceleration. In order to help him become familiar with these stumbling blocks it is proper to consider the simpler cases of motion, which is the usual practice in physics. Yet so much emphasis is placed on motions in which the acceleration is constant that some students cannot then conceive of a motion with variable acceleration. It should be pointed out that the familiar equations of motion as taught in most physics courses are, after all, only equations for a special case, and that the general equations are really those derivatives and integrals relating displacement, velocity, acceleration, and time. Likewise, a particle moving on a circular path is almost invariably said to be subjected to a radial and a tangential acceleration. This is a convenient method which is readily grasped by the student. But should we not go on to point out that, after all, the particle has one and only one acceleration and that the radial and tangential accelerations are really only components of this one acceleration? Such a conception is almost a necessity when general curvilinear motion is considered.

Most students are extremely vague when they are asked to define the term mass, and are apt to say that the mass of a body is the quantity of matter composing the body, or is a property of the body. Some will say that it is equal to the weight of the body. Most physics textbooks contain the statements that mass is a measure of the quantity of matter in a body and that mass is a property by virtue of which the body possesses inertia. Some texts state that a body possesses mass by virtue of it inertness. Thus we seem to go in a

circle, defining mass in terms of inertia, and inertia in terms of mass. Perhaps we can do no better than that, but it certainly leaves the student a bit vague. We should at least emphasize the fact that bodies of equal mass must be given equal velocities in equal times when acted upon by equal forces. We should also point out that Newton proved experimentally that bodies of equal mass, according to this definition, are acted upon by equal gravitational forces, thus establishing the fact that the weight of a body is proportional to its mass. We should be especially careful to clarify the reasons why the weight of a given body varies depending upon the location of the body and the method of weighing and to explain when the weight of the body may be used to measure the mass.

Newton's Laws of Motion are not clearly understood by many students. Usually the student completing his course in physics can recite these laws, but quite often he cannot explain them. This tendency is not so pronounced with respect to those laws generally referred to as Newton's First and Second Laws, although many students fail to realize that all problems in equilibrium are within the scope of the first law. The large amount of misunderstanding is in connection with Newton's Third Law. The student expects to find both the action and reaction on the same particle. If the particle is in equilibrium under the action of two forces, the student feels that one force is the action and one the reaction. He forgets that those two forces must be exerted by two other particles and that the reactions are the forces on these other particles. For this particular case the results are satisfactory; hence the student feels that his view is the correct one. However, he will subsequently be confronted with the case of a particle acted upon by one force only so that it has acceleration. If he then visualizes the reaction as an equal and opposite force acting on the same particle, he will have balanced the force system so that no acceleration could exist. That such a reaction does not exist must be emphasized if the student is expected to believe Newton's Laws. It cannot be over-emphasized that a clear understanding of Newton's Third Law is a prerequisite to the use of free-body diagrams.

Closely allied to the misconceptions concerning Newton's Laws is the widespread misuse of D'Alembert's Principle. This principle merely permits the equations of motion to be written as equations of equilibrium. It is usually applied by imagining a force acting on the particle in a direction opposite to that particle's acceleration, and equal in magnitude to the product of the mass times the acceleration. This imaginary force is usually called the "inertia force." Then, since the resultant of the real forces equals the product of mass times acceleration, the "inertia force" is the equilibrant of the resultant force. Thus the equations of equilibrium may be applied. The particle is said to be in "dynamic equilibrium." Many textbooks ascribe great convenience to this method, but when one remembers that all that is really done is to transfer the mass-times-acceleration term from one side of the equation to the other, the great convenience disappears. Furthermore, it is difficult to keep in mind that the "inertia force" is purely imaginary. In the case of a body moving on a horizontal circular path the "inertia force" is mistakenly called the centrifugal force. It is forgotton that the only real forces acting on the body are the gravitational force

and the force exerted by the cord or restraining object. It is also forgotten that the radial component of the force exerted by the cord has one function only, namely, to produce the radial acceleration required to keep the body on its circular path. It does not exist to balance the "inertia force." In extreme cases, some students may even view the "inertia force" as a force urging the body outward, thus requiring the cord to exert an inward pull on the body to prevent it from moving outward. Similarly, the "inertia force" may be used to explain why a block being accelerated to the right by a force applied below its center tips "backward." Of course, such a block will tip to the left, but it does not actually tip backward. Instead, the lower part is simply accelerated to the right at a more rapid rate than the upper part. The student will remember that the upper part of his body seems to go backward as he stands in a streetcar that is accelerating, therefore, he will reason that the "inertia force" tips him backward. He forgets that the accelerating force is being transmitted to his body through his feet and legs and that this force produces a torque about the center of gravity of his body. This torque will cause him to fall backward with respect to the car unless he leans forward so that the normal pressure against his feet can produce a balancing torque. In any event, he forgets that the backward motion is only relative to the car. In view of the misunderstandings that may arise from the use of the "inertia force," is it worth the risk? The idea of "dynamic equilibrium" is inherently antagonistic to Newton's Laws of Motion anyway, so if we are to rely on those laws, and rely on them we must, why permit any conception that is not in agreement with them?

Many students in mechanics are insistent that concise and simple definitions be given for moment of inertia and radius of gyration of a body. Some textbooks attempt such definitions while others merely show that the terms $\sum mr^2$ or $\int \rho^2 dm$ appear in certain moment equations, and state that the value of these expressions for any finite body is known as the moment of inertia. The latter is the only real definition possible, and should be used. If it is used, and is supplemented with explanations, it will give the student a better conception of moment of inertia than some artificial definition. The fact that similar integrals referring to areas are also encountered in engineering, and that these integrals are also called moments of inertia, is all the more reason for using this method. A similar treatment of radius of gyration should be made. If radius of gyration is defined as the distance from the axis of rotation to a point at which the entire mass of the body could be concentrated without altering the moment of inertia, it is implied that the body has only one radius of gyration. Actually it has a radius of gyration for every such axis. Furthermore, the false idea that the radius of gyration is some measurable distance is established in the student's mind.

Finally, students in mechanics have so much trouble with units that it seems desirable to be more rigorous with units in preceding courses. In the physics course, students make many conversions of units so that they should become accustomed to giving proper attention to units in that course. Such conversions should not be made by use of constants such as $\frac{5,280}{3,600}$ to convert

miles per hour per second to feet per second per second until the student first has learned that he is really multiplying $\frac{\text{mi.}}{\text{hr.} \times \text{sec.}} \times \frac{1 \text{ hr.}}{3{,}600 \text{ sec.}} \times \frac{5{,}280 \text{ ft.}}{1 \text{ mi.}}$ in order that the miles and hours cancel out to leave feet per second per second. In writing equations and formulae, the student should learn that the two sides of the equality must be equivalent with respect to units as well as with respect to numerical values, and he should form the habit of checking both of these equalities rather than just the numerical value.

In conclusion, the writer believes that most of the deficiencies and erroneous ideas that students have stem from too little time having been allocated to the various courses. The question of how much time should be devoted to courses in pure science and the humanities compared to the time devoted to the professional courses is an old one, and an important one. There are people who say that engineering education lags five years behind engineering practice, and that may be partly true. Certainly it is not true of the courses in pure science and the humanities. If it is true of the professional courses, then we should consider whether or not all of the time spent on those courses is justified. Perhaps an increased amount of time spent on the fundamentals, which do not change appreciably, would give better results. The records of future graduates with degrees in engineering physics will be pertinent and informative as should be the records of former graduates in general science, particularly those having had considerable exposure to the engineering attitude.

Hydrographic Surveying in the Civil Engineering Curriculum

By M. O. SCHMIDT

Assistant Professor of Civil Engineering, University of Illinois

Foreword.—During the past several years there has been a tendency among civil engineering curriculum shapers to compress and trim the extent of surveying instruction. The elimination of such branches as Mining Surveying and the abbreviation of plane-table instruction typifies such action while the introduction of Photogrammetry illustrates the progressive attitude that should be accorded this fundamental civil engineering subject if it is to be adequately and efficiently presented to the student. Hence, a brief consideration of the suitability and need to devote a small portion of the allotted time to hydrographic surveying and stream-discharge measurement seems desirable.

Although hydrographic surveying is practiced by men of civil engineering training, few, if any of them, anticipated during their academic years of engaging in such an activity. Events of the past five years have served to emphasize the importance of maps and charts and the probable requirements of the future indicate, among other things, that maps, charts, and water resources data will be indispensable in the development of ocean and inland waterway transportation and in the efficient and economical control and utilization of the waters of our rivers.

Hydrography is that branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the earth's surface and the adjoining coastal areas. Hence, it includes many activities ranging from astronomic observations, triangulation, topographic surveys, tide and current studies to magnetic surveys, oceanography, and sounding operations. From a broad point of view the term, hydrographic surveying, includes all the above activities and has as its principal object the procurement of data necessary for the compilation of a nautical chart. The U. S. Coast & Geodetic Survey of the Department of Commerce and the Hydrographic Office of the U. S. Navy have been especially active during the war years executing hydrographic surveys of many types. In spite of the remarkable advances made in navigation methods, there will always remain the need to have accurate, adequate, and up-to-date charts since without such charts lighthouses, buoys, and other aids to navigation will not be related in position with respect to one another, the ship, and with submarine features, and topography. It would have been difficult to understand ten years ago why we here in the United States should have good charts of Tarawa and good maps of Italy but the events that have transpired since then have warned us that global maps

and charts may be needed at any time and that the completion not of a national atlas but of a world atlas has become a vital necessity. A good part of this data can be judiciously borrowed in time of peace.

Few engineers are conversant with the work of the U. S. Lake Survey whose primary function is to execute hydrographic surveys of the Great Lakes and to insure with its charts the safety of water-borne commerce from Duluth to the St. Lawrence River. These surveys cover not only the inshore waters and the open lakes, but a strip along the shore as well so that landmarks are provided for navigation. The width of this strip is generally about a half-mile and is fully controlled by the primary triangulation net covering the Great Lakes which was established by the Lake Survey Office between 1865 and 1875 and which has since been supplemented by recent surveys. It is interesting to mention that Professor J. B. Johnson, one of the earliest presidents of S.P.E.E., worked as an Assistant Engineer on these early lake surveys. The U. S. Corps of Engineers has had much to do with the improvement of our many river avenues of transportation and the comprehensive Rivers and Harbors Bill recently passed by the Congress promises a vast program of internal waterway improvement. The Canalization of the Upper Mississippi River is an outstanding example of this type of activity. The erection of many dams in the West impounding the waters of silt-laden streams has stimulated a great deal of study concerning the accumulation in the reservoirs of sediment whose depth and extent would be revealed by a well-executed hydrographic survey. The decision as to whether the St. Lawrence Waterway should be built depends, it is true, largely upon political considerations, but factual hydrographic survey data are required for any kind of an engineering analysis. The results of hydrographic surveys are also valuable for the study of beach erosion and certainly for military defense.

In general, then, the basic operations of making soundings and of locating these soundings and any features on or below the surface of a body of water should be known to the civil engineer and the teacher of surveying should be sufficiently familiar with the development of the art so that he can point out the methods in current use rather than resort to a demonstration of practices which may now be obsolete.

The measurement of stream flow is intimately related to the science of Hydrology and is taught in some engineering schools as a part of the hydrology course. There are, nevertheless, many colleges whose civil engineering curricula do not include hydrology.

The requirements of our war industries and of our growing cities have demonstrated that a plentiful supply of water of good quality is one of the most valuable assets of any community, state, or nation.

Any kind of planning whether it be local or regional is essentially an engineering process and water planning, dealing as it does with one of the most important natural resources of the country, requires adequate information on the variations in stream flow, the quantities of water available and the ranges of stage that may be expected. Such information is essential to the design and construction of hydraulic works of all kinds, including structures for flood protection, navigational developments, irrigation systems, and

* Italicize.

municipal supplies. Such data are also required for the establishment of railroad and highway elevations and the design of bridge and culvert openings.

Since 1895 the Water Resources Branch of the U. S. Geological Survey has been carrying out a systematic program of stream-flow measurement and run-off compilation and its many hundreds of water supply papers represent data of inestimable value to the nation. This organization employs a relatively small number of engineers all of whom are civils since the Survey feels that civil engineering training is required to inculcate the professional attitude towards stream flow measurements that the Survey so much desires. Furthermore, a higher degree of competency for dealing with hydrological and meteorological studies is thereby insured.

The preceding discussion may serve to justify the small amount of time that is spent at our summer survey camps in hydrographic surveying and may be sufficient encouragement to the individual teacher of surveying who does not now treat of this subject to devote a few classroom hours to an exposition of the mechanics of such operations and to develop some small degree of appreciation in the student of this branch of surveying.

Summary Report of National Conference on International Educutional Reconstruction*

By S. S. STEINBERG

Dean, College of Engineering, University of Maryland

At the request of President Croft of the Society, the speaker attended this Conference in Washington, D. C., on November 22 and 23, 1946, convened by the Commission for International Educational Reconstruction as an American contribution to the celebration of UNESCO month. Leaders of more than 100 national organizations—educational, scientific, civic, religious, relief and labor—attended to consider the plight of youth and the condition of education in the war-devastated countries. At the end of the two-day session the delegates to the Conference returned home convinced that if peace is to be preserved, the United States must do more than provide relief for the war-devastated countries in the form of food, clothing and medicines. They agreed that vast voluntary efforts are needed to aid the victims of war to rebuild their schools and educational systems, their libraries and museums, their universities and laboratories. They were convinced that the success of UNESCO, the educational arm of United Nations, depends on restoring educational opportunity to all countries of the world; and the rehabilitation of the mind is as important as rehabilitation of the body.

All participants in the Conference agreed that speedy action is needed to save the "lost generation" of the countries occupied by the enemy. These youths, aged 10 to 20, have suffered hunger, cold, disease and the terrors of war and enemy occupation. Their education has been neglected or has been received almost entirely under Axis direction. It seemed to the conferees that both humanitarianism and enlightened self-interest demand that these youths receive at least a minimum education. If they remain uneducated, semi-literate, unskilled, unable to aid in the rehabilitation of their countries, then they may become embittered and follow authoritarian leaders. If neglected today they may become the soldiers whom our children must face on the battlefield tomorrow.

Reports presented at the Conference, both verbal and with motion pictures taken by the U. S. Army and special investigators, showed that two years after liberation, thousands of children in Europe are still without schools and still lack even the simplest educational materials, such as books, pencils and paper. In some of the countries more than one-third of the school buildings have been destroyed or badly damaged. Few teachers have been trained since the beginning of the war. Libraries and museums have been stripped or

* Presented at the meeting of General Council, American Society for Engineering Education, Chicago, December 17, 1946.

burned. The motion pictures were most revealing; they clearly showed the deprivations, the devastations, the miseries and the handicaps which the youth, as well as their elders, have suffered and are now facing.

Among the major recomendations of the Conference were the following:

1. The urgent importance of providing educational supplies and materials. It was recommended that these be allotted without discrimination as to race, creed, color or political belief and that aid not only go to the former allied nations but to displaced children and to former enemy nations as well.

2. Steps should be taken to see that those aided are those in greatest need and to insure adequate reporting from recipient to donor.

3. Increased efforts by Federal, industrial and private agencies to meet the utter lack in many areas of books and periodicals was recommended with the suggestion that such aid be provided for at least two years.

4. It was urged that special assistance be provided to teachers, including financial assistance to permit them to buy basic essentials since inflation has impoverished the teaching profession in most countries.

5. The Conference emphasized the importance of educational missions of all types. Foreign educational leaders should be brought to the United States for short periods of observation and study, and expert educational advisors should be offered to the war-devastated countries.

6. The provision of thousands of fellowships and scholarships in American universities for advanced foreign students was urged. To this end the passage of the Bloom Bill and the speedy implementation of the Fulbright Act were favored. Study grants are particularly needed now for mature experts in technical and educational fields in which marked advances have been made in the United States during the war years. It was urged that visas and immigration laws be relaxed in order to permit freer travel by foreign students. Larger fellowship stipends for foreign students were recommended. It was suggested that orientation courses be provided to help foreign students adapt to American ways and conditions.

7. The State Department was urged to appoint more American cultural attaches abroad to bring about better reporting about educational conditions and to approve selection of candidates for fellowships.

8. The importance of "volunteer service groups," sometimes known as "educational work camps," was urged in order to provide American students with an opportunity to join with the students of other countries in rebuilding destroyed schools and other public facilities.

In closing, the speaker would add that not until one attends a conference such as this, and learns at first hand the conditions that confront the youth of the war-devastated countries, does one fully realize how blessed we were as a nation and as individuals that the late war did not actively touch our shores.

Quick Courses in Reading Foreign Language for Science and Engineering Graduate Students*

By WILLIAM N. LOCKE

Head, Dept. of Modern Languages, Massachusetts Institute of Technology

Advanced students and research men in science and engineering need to be able to consult important technical publications in other languages. To help them get the essential minimum understanding, new courses in reading scientific French, German, and Russian have been developed at the Massachusetts Institute of Technology. This is a brand new type of course with methods adapted to its specific aim of teaching the individual graduate student in one semester to read technical material in his own field.

All Doctoral candidates at M.I.T. are required to "demonstrate to the Department of Modern Languages the ability to read scientific literature in their field of specialization in English and in two other modern languages acceptable to the department in which they are enrolled." Master's degree candidates in some fields are required to have a reading knowledge of one modern foreign language. These requirements are met by the translation at sight of a page or two of technical material into clear, idiomatic English. But the great problem in this connection has been how the student was to get a sufficient knowledge of the technical foreign language to pass an examination, without taking up a great deal of his valuable time.

Until 1945 students were left to their own devices to get ready for the language examinations. To be sure, they could take one or more of the undergraduate courses, the purpose of which at the elementary stages was to give a general view of the language, a foundation on which to build a reading or speaking knowledge of the languages; but these courses were not specifically designed to prepare for reading scientific material. If the graduate student could afford to spend time enough to go on into the third and fourth semesters of the undergraduate language courses, there he would read technical material in the various fields. If he were fortunate enough to have studied some German, and possibly French, as an undergraduate or in high school, then by some careful reading of technical literature, he could prepare himself for the language requirement without taking further courses. Some men with no previous knowledge of the languages they needed even prepared themselves entirely alone, with-

* In answer to a question: "Are the methods of language instruction available to graduate students pitched at a mature level and aimed to develop systematic language habits in keeping with other disciplines of graduate instruction?" from "A Manual of Graduate Study in Engineering," by the Committee on Graduate Study of the S.P.E.E., THE JOURNAL OF ENGINEERING EDUCATION, Vol. 35, No. 10, June 1945.

out the help of any courses, only possibly some assistance from a roommate or friend. It was said that the average amount of time needed to prepare a man through self-study was 250 hours. Thus, the lack of any effective assistance to graduate students in preparing for the reading requirement made it a much more difficult hurdle than it needed to be.

At other technical and scientific schools throughout the country, the problem has been similar, and although there have been some attempts to help graduate students in getting by the language requirement, this has generally been an extension of the assistance-from-a-roommate-or-friend idea, with a member of the staff sitting down with a few students to read foreign language material with them. The problem used to be further complicated at M.I.T., and still is at some other institutions, by the fact that the men were required to be able to read the literary as well as the scientific language, or even instead of the scientific language. It is obvious that there are large differences of construction and vocabulary between these two types of language.

The relative simplicity of the problem at M.I.T. now, namely, the fact that the student need read only technical material in his own field, made it seem that some simple and direct solution should be possible, avoiding the waste motion inevitable in self-study and, by the use of experienced teachers, reducing the time needed to a minimum.

In the summer of 1945, the Department of Modern Languages presented to the Graduate School Committee at the Institute a plan for setting up graduate courses in German, French, and Russian. These courses would be open only to graduate students and they were to be only one semester long. They would dispense with the formal study of grammar, make no attempt to teach the men to speak or to understand the spoken language, but would concentrate solely on reading technical material in their own field. The question was immediately asked, how would it be possible to have graduate students from ten or twenty different fields in a single course? The answer was that all the men would meet together once a week for discussion of linguistic peculiarities common to all fields, such as case formation, verb tenses, and sentence structure; then the representatives of each different field were to have separate section meetings twice a week where they would do their reading.

This treatment of language purely as a tool has been criticized at the Institute and outside. It is true that modern languages are spoken languages, and if you neglect the hearing and speaking of them you have reduced them to dead languages. It is true that language can be an introduction to the civilization of the foreign country, leading to a better understanding of the world and ourselves. Yet what graduate students in science and engineering specifically need is a tool, a key to unlock the door to the scientific literature in a foreign language. To give them this key as quickly and efficiently as possible was the purpose of these new courses.

The first course was in German and was offered in the fall of 1945. Many of the students and even some of the instructors doubted whether it would really be possible in one semester to accomplish enough to get men ready for the reading requirement examination. Sixty-six men took the course. By the end of the first month, those who had had considerable German previously were doing very well, but those

with no previous study were discouraged; the intricacy of German thought patterns was overwhelming. So a fourth hour per week was added on an entirely optional basis, during which beginners and any others who felt particularly weak were able to bring up problems, no matter how small, and get them thrashed out in a way which was impossible in the large group where the situation was likely to be to some extent dominated by the majority who had had some German. In the middle of December, something happened. The men with the poor background in German, or none, suddenly found that it was beginning to make sense. From then on it was obvious that the experiment was going to work and at the end of the semester sixty-two out of sixty-six men in the course passed the reading requirement. All but one who had ever had any previous German passed, and of sixteen with none, all but three passed. The aim of the course was achieved. It could be done. But another hurdle lay ahead. Could it be done in Russian?

Thirty-six hardy souls started in the course in Russian in the spring of 1946, many feeling that they were doing it against their better judgment. Several were members of the Institute staff who were only taking it for their own satisfaction. At the end of the semester, twenty-three men took the reading requirement examination; 16 passed. Even some of those who failed expressed satisfaction at the amount of progress that they had made in the course. The feeling of those who had studied French or German previously seemed to be that except for the alphabet, scientific Russian is not any harder than scientific German. This should encourage others to attempt Russian, since there is no doubt that in many fields the Russians are now publishing scientific material of great importance. This is particularly true in chemical engineering, where Doctoral candidates are now being advised to take German and Russian instead of German and French.

In the same type course given in French in the summer of 1946, seventy-four men were enrolled, sixty-five took the examination and sixty-four passed. These results seem to prove what everyone always suspected, that as French gets more technical, it gets more like English and therefore easier; whereas German, as it gets more technical, gets harder. Russian, fortunately, uses large numbers of words borrowed from German and French in the technical language so that it, too, is easier in technical than in literary works.

The German course was offered again in the fall of 1946 and the increased number of graduate students at the Institute plus enthusiastic reports on the part of men who had taken the various courses earlier, brought 143 men to the first meeting, among them several from Harvard under a reciprocal plan whereby graduate courses in each institution are open to students of the other. One hundred thirty-nine took the reading requirement examination; 132 passed. The reduction in the percentage failing from 6 per cent in 1945 to 5 per cent in 1946 is so small that one could hardly claim any improvement in teaching techniques. However, an increased number of favorable comments on the part of the students both during the course and after the examination shows that the course was more effective the second time than the first.

We mention comments from students

because never in the experience of the men in the Department of Modern Languages at M.I.T. have so many students come in voluntarily to tell how much they enjoyed a course and how much they felt they were getting out of it—one man said he enjoyed the German course more than any other he was taking at the Institute. It must be that the men feel that here is a course which sets out to do something and does it, with constant attention to the purpose and eliminating all extraneous material. The average amount of time spent per man seems now to be about 175 hours, as opposed to the earlier 250 hours.

The choice of reading matter used in the reading sections of the courses is perhaps of interest. No textbooks specialized according to fields of study are available except in German for chemistry. Even many of these are not satisfactory because the material in them has been edited and simplified. At Tech the material used is chosen from foreign books or periodicals, the only editing being the arranging of selections so that the easier ones, *i.e.*, those most like English in vocabulary and syntax, are read first. There is no simplification of the original text, nothing translated from English into the foreign tongue to be retranslated back by the students. All the work is on a mature level, and the later selections in the course represent some of the more advanced work done in the foreign country. Some of it opens up new fields to the graduate students and one Doctoral thesis now being written at the Institute is a direct outgrowth of work read by the student in the aeronautical engineering section of the German course. Suggestions for the choice of reading material often come from the students or their own departments as well as from instructors in language who are constantly on the lookout for new material.

These graduate language courses are tool courses, leaving the cultural values of language study entirely to one side. However, there has been a real need for a practical approach to the language problem of the graduate student in science and engineering. The one-semester scientific reading courses at M.I.T. help him get the reading knowledge he needs in a minimum of time and with the least possible waste motion.

Seminars Can Be Fun!

By J. TRUEMAN THOMPSON

Professor of Civil Engineering, Johns Hopkins University

For a number of years the Civil Engineering Department of The Johns Hopkins University has conducted a Seminar which we believe is unique in both method and accomplishment. It involves directly only the fourth year undergraduate students. Both they and the Staff agree that this weekly hour is the most enjoyable and profitable one in our curriculum. The purpose of this brief paper is to record the objectives, methods, and results of the Seminar for the guidance of those who may wish to consider a similar undertaking.

The objectives of the Seminar are: to provide a practice forum, in an atmosphere of great informality, in which to gain experience and confidence in self-expression; to widen horizons and afford vistas into fields other than engineering; to teach how to organize and conduct in an orderly fashion a meeting of interest and wills which are often in conflict; and to let one see, at an early age, what one's own manuscripts look like in type and to sense the thrill of authorship.

To attain these objectives we have developed over the years a program which we think works successfully. The first semester is given over almost entirely to instruction and practice in speaking—not in oratory, but in clear, convincing speech. The sections are small enough to warrant that nearly every time we meet everyone will have a chance to speak before his group. He begins perhaps by telling, for a minute or two, of a movie he has recently seen or of what he did during the summer. Gradually he is led along to discussions of greater importance, culminating, perhaps, in a ten minute argument in favor of some local civic improvement before his section, sitting as a critical, if fictitious, City Council.

And all the while he is being helped by friendly criticism. Generally he is his own most valuable critic, for early in the game we record one of his first efforts and give him the disk so that he may hear himself as others hear him. It seldom fails to promote improvement, especially in diction. And, as an encouraged act of section participation, he gets advice from his peers. What they fail to catch, his instructors are likely to pick up.

It is fair to ask, at this point, where one may find qualified instructors in sufficient numbers to keep the sections small. In our experience, one doesn't find them, he makes them! The average teacher of engineering with an above-average *interest*, even though inexperienced in this field, will make a good section leader with the help of a few coach-conference suggestions and the use of one or two of the many texts that are available.

Toward the end of the first semester, instruction and practice in parliamentary procedures are begun. This is in preparation for the second semester in

which the Seminar is conducted as though it were, let us say, a local section of a Professional Society. "Robert's Rules of Order" becomes our Bible; the functions of officers are understood; a constitution and by-laws of our own making are drawn; weekly rotation of officers is provided for; a gavel and a minute book appear; and lastly and most importantly, a program of speakers for the weekly meetings of the second semester is adopted.

These weekly meetings, which are run by the Seniors, are scheduled at an hour that permits maximum attendance of Staff and graduate students. And, mirabile dictu, *Art* students have been known to put in an appearance, attracted by the variety of the programs (we encourage non-engineering subjects as far as possible) and the liveliness of the discussions.

The business portion of the agendum is where most of the fun comes in. Reversing usual practice, we put this last in our agenda because sometimes we become so entangled in parliamentary tape that it is past quitting time before we can extricate ourselves. But the boys love it and even though the business itself is unimportant and is largely manufactured in advance by those who *aren't* going to be officers that day, the principles are worth fighting for and the battle of wits goes on to a final conclusion, sometimes even in the face of the undebatable motion to adjourn. We've found a way to get around that one!

The subjects of the papers of the second semester are chosen by the students from a list prepared by the Staff. Preference is given to non-engineering subjects, for it is a studied purpose of the course to engender interest in a variety of fields. The following few titles are illustrative of the many that have been used:

An Engineer's Reflection on Penology
Mohandas K. Gandhi—A Thorn in the Lion's Paw
The Financial Plight of our Cities
Socialized Medicine
Conservation Policies in Maryland
The Industrial Revolution in the Southern States
The Evolution of American Architecture
Controversies in Organized Labor

Well in advance of its presentation, the paper must be reviewed by a Staff member. We use this as an opportunity not only to reassure ourselves that our people can write, but that they are aware of the manner in which a manuscript should be prepared for publication, say in a professional journal. Accordingly, we rather rigidly prescribe the format—cover sheet, index, text, conclusions, bibliography, etc.

We also believe that it is good to inculcate a sense of pride in authorship. So as soon as the paper is approved we reproduce it in sufficient quantity that everyone in the Seminar may have a copy. At the end of the year these may be bound in some inexpensive way and form not only a useful reference source but a pleasant souvenir as well.

When the paper is presented it is not read from manuscript but is given extemporaneously from notes on a couple of inconspicuous cards. The speaker is introduced by the Chairman, uses, if he cares to, a projection device for his illustrations, and, finally, defends his conclusions in the ensuing discussion by his fellow students and the Staff.

The arrangements pictured above may appear somewhat formidable, but in

reality they are not. It is not to be denied that the Staff, and particularly the person in charge of the course, is put to some trouble, but we think the time, energy, and trivial amounts of money which we spend yield magnificent returns.

The sine qua non of such a Seminar is interest, and its lubricant is fun! We have developed an unusual interest on the part of our Staff and this is contagious among the students. The contagion is incubated in a medium of enjoyment. They enjoy the relief from technology afforded by the chance to hear from one of their fellows what he has learned by special study and interviews in the fields of sociology, politics, international relations, economics, labor, religion, art. They respectfully enjoy the equality with Staff which membership and equal votes in the Seminar give them. They enjoy the fun we have in the make-believe business they concoct to try out resolutions, motions, amendments and all the other devices of organized meetings. And, "Whisper it not in the streets of Ascalon . . ." they sometimes enjoy the ineptitude of presiding officers at professional meetings to which they are purposefully taken.

And all the while they are using speech—using it consciously and publicly and with the help of constructive criticism. That, after all, is what the Seminar wants most of all to accomplish. We are pleased with it.

New Members

BENISH, ANTHONY A., Assistant Professor of Civil Engineering, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

BUCHTA, J. WILLIAM, Chairman, Dept. of Physics, University of Minnesota, Minneapolis, Minn. B. J. Robertson, T. E. Murphy.

CONTE, FRANK J., Dean, Pre-Engineering Curriculum, Associated Colleges Upper N. Y., Mohawk College, Utica, N. Y. E. B. Phillips, J. A. Dunlop.

DUFFIN, DANIEL J., Editor, Industrial and Business Libraries, McGraw-Hill Book Co., N. Y. C. J. W. Wight, J. W. Taylor.

FULLING, JOHN C., Personnel Supr., Engineering, E. I. duPont de Nemours & Co., Inc., Wilmington, Del. T. H. Chilton, M. J. Bergen.

GEER, ELIHU, Assistant Professor of Civil Engineering, University of Detroit, Detroit, Mich. G. P. Hanley, Jasper Gerardi.

GRIFFIS, WILLIAM K., Assistant Professor of Mechanical Engineering, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

GUILLARD, EUGENE, Assistant Professor of Civil Engineering, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

HARTMAN, JAMES B., Research Associate in Mechanical Engineering, Lehigh University, Bethlehem, Pa. F. V. Larkin, B. K. Eldoss.

HOGAN, JOSEPH C., Instructor in Electrical Engineering, University of North Dakota, Grand Forks, N. D. C. H. Buchanan, P. J. Potter.

HOVER, JOSEPH P., Instructor in Civil Engineering, University of Detroit, Detroit, Mich. J. J. Uicker, G. B. Uicker.

HOWARD, DAVID G., Professor of Electrical Engineering, U. S. Naval Academy, Annapolis, Md. J. Ellis, R. C. Turner.

KAMM, ALBERT J., Assistant Professor of Drawing, University of Buffalo, Buffalo, N. Y. J. A. Beane, R. K. Smith.

KREISLE, LEONARDT F., Instructor in Mechanical Engineering, University of Texas, Austin, Texas. B. E. Short, V. L. Doughtie.

LINDSEY, EDGAR E., Assistant Professor of Chemical Engineering, University of Tennessee, Knoxville, Tenn. R. M. Boarts, N. W. Dougherty.

LINVILLE, THOMAS M., Staff Assistant to Manager of Engineering, General Electric Co., Schenectady, N. Y. P. L. Alger, A. C. Stevens.

LITTLE, SIDNEY W., Dean, School of Architecture, University of Oregon, Eugene, Ore. F. L. Bishop, Nell McKenry.

LONGWELL, JOHN H., President, North Dakota Agricultural College, Fargo, N. D. R. M. Dolve, H. S. Dixon.

MOORE, WALTER L., Associate Professor of Civil Engineering, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

OLIPHINT, JOSEPH B., Assistant Professor of Mechanical Engineering, University of Texas, Austin, Texas. B. E. Short, V. L. Doughtie.

PANANIDES, NICHOLAS A., Instructor in Mathematics and Engineering, Bakerfield Jr. College, Bakersfield, Calif. W. L. Johnson, F. L. Bishop.

PERKINS, ROY B., Instructor in Drawing, University of Illinois, Navy Pier, Chicago, Ill. R. P. Hoelscher, J. C. Chaderton.

RIPPERGER, EUGENE A., Instructor in Engineering Mechanics, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

ROSE, KENNETH E., Assistant Professor of Mechanics and Metallurgy, University of Oklahoma, Norman, Okla. R. V. James, F. G. Tappan.

SAAD, MICHEL A., Instructor in Engineering Mechanics, University of Texas, Austin, Texas. P. M. Ferguson, W. M. Honour.

SMITH, HAROLD W., Instructor in Electrical Engineering, University of Texas, Austin, Texas. V. L. Doughtie, W. R. Woolrich.

SMITH, STANLEY A., Head, Architectural Engineering State College of Washington, Pullman, Wash. E. Moore, R. D. Sloan.

TINNING, GEORGE M., Instructor in Engineering, Detroit Institute of Technology, Detroit, Mich. C. C. Winn, L. L. Henry.

UPSON, RALPH H., Professor of Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. N. F. Ruszaj, H. C. T. Eggers.

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